Manual on the WMO Integrated Global Observing System

Annex VIII to the WMO Technical Regulations

2021 edition

WEATHER CLIMATE WATER

WORLD METEOROLOGICAL ORGANIZATION

WMO-No. 1160

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EDITORIAL NOTE

The following typographical practice has been followed: Standard practices and procedures have been printed in **bold**. Recommended practices and procedures have been printed in regular font. Notes have been printed in smaller type.

METEOTERM, the WMO terminology database, may be consulted at https://public.wmo.int/en/meteoterm.

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INTRODUCTION

General

1. This is the third edition of the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160), which was approved by the World Meteorological Congress at its extraordinary session in 2021 in order to take into account the establishment of the Global Basic Observing Network. It replaces the second edition, which was approved by the Eighteenth World Meteorological Congress. The first edition was issued following the decision of the Sixteenth Congress to proceed with the implementation of the WMO Integrated Global Observing System (WIGOS) and it was further developed in line with the decision of the Seventeenth Congress to proceed with the preoperational phase.

2. The Manual was developed by the Executive Council through its Inter-Commission Coordination Group on WIGOS, specifically its Task Team on WIGOS regulatory material. It is the result of a collaborative approach involving all interested technical commissions under the leadership of the former Commission for Basic Systems (CBS) and the former Commission for Instruments and Methods of Observation (CIMO).

Purpose and scope

3. The Manual is designed:

(a) To specify the obligations of Members in the implementation and operation of WIGOS;

(b) To facilitate cooperation in observations among Members;

(c) To ensure adequate uniformity and standardization in the practices and procedures employed in achieving (a) and (b) above.

4. The Manual is Annex VIII to the *Technical Regulations* (WMO-No. 49) and should be read in conjunction with the three volumes and the set of annexes which together make up the *Technical Regulations*. Gradually, all technical regulations for all WMO component observing systems will be included in WIGOS.

5. Members will implement and operate their observing systems in accordance with decisions of Congress, the Executive Council, the technical commissions and regional associations. Where those decisions are technical and regulatory in nature, they will in due course be documented in the Technical Regulations.

6. In essence, the Manual specifies what is to be observed and what practices and procedures are to be followed in order to meet the relevant observational requirements of Members. These requirements may arise directly at a national level or collectively through WMO Programmes at global or regional levels, and are expressed through the application areas of the Rolling Review of Requirements. A number of other Manuals and Guides provide more practices and procedures on the operation of observing systems including stations and platforms, instruments and methods of observation, and on reporting and management of observations and observational metadata.

7. In the case of hydrological observations, there is not a widely implemented base of global exchange and global standard practices and procedures. *Technical Regulations* (WMO-No. 49), Volume III, provides Members with predominantly recommended practices and procedures. In order to help ensure the quality and comparability of observations within WIGOS, Members making their hydrological observations available through the WMO Hydrological Observing System (WHOS) are requested to comply with the provisions specified within the present Manual. For this reason, a number of provisions that are recommended practices and procedures for hydrology in *Technical Regulations,* Volume III, are listed as standard practices

and procedures in the present Manual. It is recognized that it might not be easy for some of the WIGOS standard practices and procedures to be widely and quickly implemented by all Members for their hydrological observations. Nonetheless, Members are urged to do their best to implement the WIGOS standard practices and procedures in the collection and exchange of hydrological observations and to make such observations available through WHOS.

Appendices

8. Appendices are used where a set of provisions on a single topic might, due to its detailed nature and length, otherwise interrupt the flow of the relevant section of the present Manual. Moreover, appendices are used to facilitate the ongoing review and update process by identifying subsections that fall under the responsibility of a particular group.

GENERAL PROVISIONS

The General Provisions to the Technical Regulations, formerly a part of the present Manual, can be found in the publication *Technical Regulations* (WMO-No. 49), Volume I – General Meteorological Standards and Recommended Practices.

APPENDIX. PROCEDURES FOR AMENDING WMO MANUALS AND GUIDES THAT ARE THE RESPONSIBILITY OF THE COMMISSION FOR OBSERVATION, INFRASTRUCTURE AND INFORMATION SYSTEMS

Note: This Appendix is currently being revised in accordance with Recommendation 11 (INFCOM-1) – Amendments to the *Technical Regulations, Volume I – General Meteorological Standards and Recommended Practices* (WMO-No. 49) Part I – The WMO Integrated Global Observing System and to the *Manual on the WMO Integrated Global Observing System* (WMO-No. 1160).

1. DESIGNATION OF RESPONSIBLE BODIES

The Commission for Observation, Infrastructure and Information Systems (INFCOM) shall designate one of its Standing Committees as the body responsible for each manual within its purview, as well as for the guides associated with that manual. The designated Standing Committee may, in turn, choose to designate one of its Expert Teams as the body responsible for managing changes to all or part of a manual or guide; if no Expert Team is so designated, the Standing Committee in question shall take on the role of the responsible body.

2. GENERAL VALIDATION AND IMPLEMENTATION PROCEDURES

2.1 Proposal for an amendment

An amendment to a manual or a guide managed by INFCOM shall be proposed in writing to the Secretariat. The proposal shall specify the need for, purpose of and requirements associated with the amendment and shall include information regarding a contact point for technical matters.

2.2 Draft recommendation

The body responsible for managing changes to the relevant part of a manual or a guide, supported by the Secretariat, shall validate the stated requirement (unless it is consequential to an amendment to the WMO Technical Regulations) and shall develop a draft recommendation to respond to the requirement, as appropriate.

2.3 Procedures for approval

After the draft recommendation drawn up by the responsible body is validated in accordance with the procedure given in section 7 below, the responsible body should select one of the following amendment approval procedures:

(a) Simple (fast-track) procedure (see section 3 below);

(b) Standard procedure (adoption of amendments between INFCOM sessions) (see section 4 below);

(c) Complex procedure (adoption of amendments during INFCOM sessions) (see section 5 below).

2.4 Implementation date

The responsible body should propose an implementation date in order to give WMO Members sufficient time to implement the amendments after the notification date. For procedures other than the simple (fast-track) procedure, if the time between the notification date and the implementation date is less than six months, the responsible body shall document the reasons for this shortened timeframe.

2.5 Urgent introduction

Notwithstanding the above-mentioned procedures, as an exceptional measure, the following procedure shall be used to introduce elements in lists of technical details or to correct errors if there is an urgent need to do so:

(a) A draft recommendation developed by the responsible body shall be validated according to the steps defined in section 7 below;

(b) The draft recommendation for the preoperational use of a list entry, which can be used in operational data and products, shall be approved by the chair of the responsible body, the chair of the responsible Standing Committee, and the president of INFCOM. A listing of preoperational list entries is kept online on the WMO web server;

(c) Preoperational list entries shall be submitted for approval by one of the procedures in 2.3 above for operational use;

(d) Any version numbers associated with the technical implementation should be incremented at the least significant level.

2.6 Issuing the updated version

Once amendments to a manual or a guide are adopted, an updated version of that manual or guide shall be published in the languages agreed upon for its publication. The Secretariat shall inform all Members of the availability of a new, updated version of the manual or guide in question on the notification date mentioned in 2.4 above. If the amendments are not incorporated into the published text of the relevant manual or guide at the time of the amendment, there should be a mechanism to publish the amendments at the time of their implementation and to retain a permanent record of the sequence of amendments.

3. SIMPLE (FAST-TRACK) PROCEDURE

3.1 Scope

The simple (fast-track) procedure shall be used only for changes to components of the manual that have been designated and marked as "technical specifications to which the simple (fast-track) procedure for the approval of amendments may be applied".

Note: One example of changes which are frequently approved via the simple (fast-track) procedure is the addition of code list tables in the *Manual on Codes* (WMO-No. 306), Volume *I.2*.

3.2 Endorsement

Draft recommendations developed by the responsible body, including the implementation date for the amendments, shall be submitted to the chair of the relevant Standing Committee for endorsement.

3.3 Approval

3.3.1 *Minor adjustments*

Correcting typographical errors in descriptive text is considered a minor adjustment and will be done by the Secretariat in consultation with the president of INFCOM. See Figure 1.

Figure 1. Adoption of amendments to a manual by minor adjustment

3.3.2 *Other types of amendments*

For other types of amendments, the English version of the draft recommendation, including an implementation date, should be distributed to the focal points for matters concerning the relevant manual for comments, with a deadline of two months for the reply. It should then be submitted to the president of INFCOM, who will consult with the president of the Commission for Weather, Climate, Water and Related Environmental Services and Applications (SERCOM) if SERCOM is affected by the change. If endorsed by the president of INFCOM, the change should be passed to the President of WMO for consideration and adoption on behalf of the Executive Council (EC).

3.3.3 *Frequency*

Amendments approved through the simple (fast-track) procedure are usually implemented twice a year: once in May and once in November (see Figure 2).

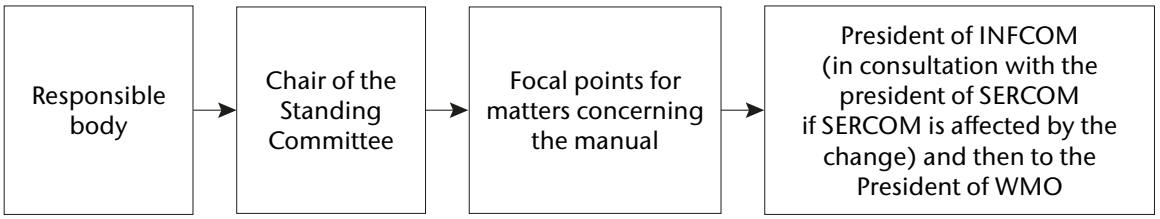

Responsible body
Chair of the Standing Committee
Focal points for matters concerning the manual
President of INFCOM (in consultation with the president of SERCOM if SERCOM is affected by the change) and then to the President of WMO

Figure 2. Adoption of amendments to a manual by the simple (fast-track) procedure

4. STANDARD PROCEDURE (ADOPTION OF AMENDMENTS BETWEEN INFCOM SESSIONS)

4.1 Scope

The standard procedure (adoption of amendments between INFCOM sessions) shall be used for changes that have an operational impact on those Members that do not wish to exploit the change but only a minor financial impact, or for changes that are required to implement changes to the *Technical Regulations* (WMO-No. 49), Volume II – Meteorological Service for International Air Navigation.

4.2 Approval of draft recommendations

For the direct adoption of amendments between INFCOM sessions, the draft recommendation developed by the responsible body, including an implementation date for the amendments, shall be submitted to the chair of the responsible Standing Committee and the president and co-vice-presidents of INFCOM for approval. The president of INFCOM shall consult with the president of SERCOM if SERCOM is affected by the change. In the case of recommendations in response to changes to the *Technical Regulations* (WMO-No. 49), Volume II – Meteorological Service for International Air Navigation, the president of INFCOM shall consult with the president of the SERCOM.

4.3 Circulation to Members

Upon approval of the president of INFCOM, the Secretariat sends the recommendation to all Members in the languages in which the manual is published, including the implementation date for the amendment, for comments to be submitted within two months following the dispatch of the amendments. If the recommendation is sent to Members via electronic mail, there shall be a public announcement of the amendment process including the relevant dates, for example by WMO Operational Newsletter on the WMO website, to ensure that all relevant Members are informed.

4.4 Agreement

Those Members not having replied within the two months following the dispatch of the amendments are implicitly considered as having agreed to the amendments.

4.5 Coordination

Members are invited to designate a responsible focal point to discuss any comments/disagreements with the responsible body. If the discussion between the responsible body and the focal point cannot result in an agreement on a specific amendment by a Member, this amendment will be reconsidered by the responsible body. If a Member cannot agree that the financial or operational impact of the amendment is minor, the redrafted amendment shall be approved by the complex procedure (adoption of amendments during INFCOM sessions) described in section 5 below.

4.6 Notification

Once an amendment is agreed upon by Members, and after consultation with the chair of the responsible Standing Committee, the co-vice-presidents of INFCOM and the president of INFCOM (who should consult with the president of SERCOM if SERCOM is affected by the change), the Secretariat shall simultaneously notify the Members and the members of EC of the approved amendments and their implementation date (see Figure 3).

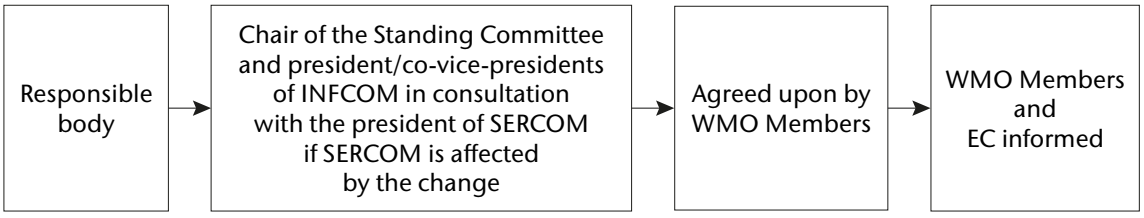

Responsible body
Chair of the Standing Committee and president/co-vice-presidents of INFCOM in consultation with the president of SERCOM if SERCOM is affected by the change
Agreed upon by WMO Members
WMO Members and EC informed

Figure 3. Adoption of amendments between INFCOM sessions

5. COMPLEX PROCEDURE (ADOPTION OF AMENDMENTS DURING INFCOM SESSIONS)

5.1 Scope

The complex procedure (adoption of amendments during INFCOM sessions) shall be used for changes for which the simple (fast-track) procedure or the standard procedure (adoption of amendments between INFCOM sessions) cannot be applied.

5.2 Procedure

For the adoption of amendments during INFCOM sessions, the responsible body submits its recommendation, including the implementation date for the amendments, to the INFCOM Management Group. The recommendation is then passed to the president of SERCOM for consultation, if SERCOM is affected by the change, and to an INFCOM session that shall be invited to consider the comments submitted by the presidents of the technical commissions. The document for the INFCOM session shall be distributed no later than 45 days before the opening of the session. Following the INFCOM session, the recommendation shall then be submitted to EC at its session for a decision (see Figure 4).

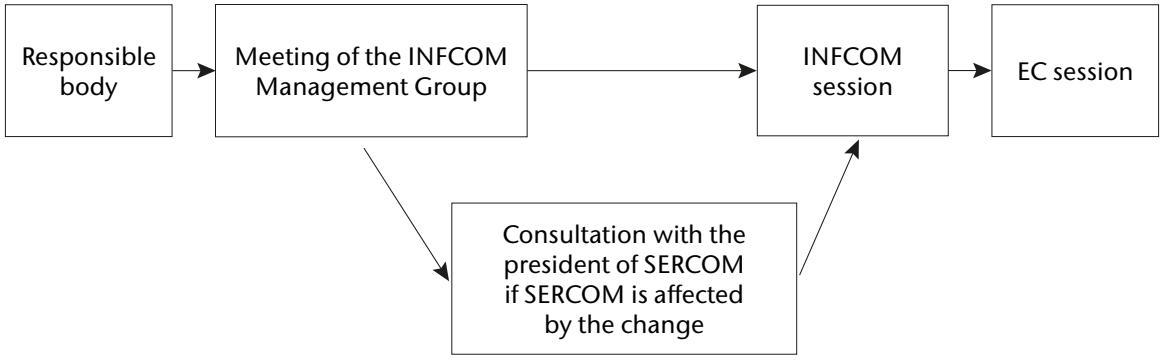

Responsible body
Meeting of the INFCOM Management Group
INFCOM session
EC session
Consultation with the president of SERCOM if SERCOM is affected by the change

Figure 4. Adoption of amendments during INFCOM sessions

6. PROCEDURE FOR CORRECTING THE CONTENTS OF A MANUAL

6.1 Correcting errors in items within a manual

Where a minor error in the specification of an item that defines elements within a manual is found, for example, a typing error or an incomplete definition, the item shall be amended, and the manual shall be republished. Any version numbers associated with items edited as a result of the change should be incremented at their lowest level of significance. If, however, the change has an impact on the meaning of the item, a new item should be created and the existing (erroneous) item marked as deprecated. This situation is considered a minor adjustment according to 3.3.1 above.

Note: An example of an item for which this type of change applies would be a code list entry for the Table Driven Code Forms or the WMO Core Metadata Profile in which the description contains typographical errors that can be corrected without changing the meaning of the description.

6.2 Correcting an error in the specification of how conformance with the requirements of the manual can be checked

If an erroneous specification of a conformance-checking rule is found, the preferred approach is to add a new specification using the simple (fast-track) procedure or the standard procedure (adoption of amendments between INFCOM sessions). The new conformance-checking rule should then be used instead of the old rule. An appropriate explanation shall be added to the description of the new conformance-checking rule to clarify the practice along with the date of the change.

Note: An example of such a change would be correcting a conformance-checking rule in the WMO Core Metadata Profile.

6.3 Submission of corrections of errors

Changes involving corrections to errors shall be submitted through the simple (fast-track) procedure.

7. VALIDATION PROCEDURE

7.1 Documentation of need and purpose

The need for and purpose of the proposal for changes should be documented.

7.2 Documentation of result

This documentation shall include the results of the validation testing of the proposal as described in 7.3 below.

7.3 Testing with relevant applications

For changes that have an impact on automated processing systems, the extent of the testing required before validation should be decided by the responsible body on a case-by-case basis depending on the nature of the change. Changes involving a relatively high risk and/or impact on the systems should be tested using at least two independently developed tool sets and two independent centres. In these cases, the results should be made available to the responsible body with a view to verifying the technical specifications.

DEFINITIONS

Notes:

1. Definitions of other terms related to observing systems may be found in the *Technical Regulations* (WMO-No. 49), Volume I. Since definitions are not repeated, the reader is advised to consult this section and the corresponding one in *Technical Regulations*, Volume I.
2. Further definitions may be found in the *Manual on Codes* (WMO-No. 306), Volumes *I.1*, *I.2* and *I.3*, the *Manual on the Global Data-processing and Forecasting System* (WMO-No. 485), the *Manual on the Global Telecommunication System* (WMO-No. 386) and other WMO publications.
3. The definitions, terminology, vocabulary and abbreviations used in relation to quality management are those of the International Organization for Standardization (ISO) 9000 family of standards for quality management systems, in particular those identified within ISO 9000:2015, *Quality management systems – Fundamentals and vocabulary*.
4. It is intended that any definition related to traceability and calibration is consistent with the *International Vocabulary of Metrology – Basic and General Concept and Associated Terms*, JCGM 200:2012, (known by its French acronym, VIM) of the International Bureau of Weights and Measures (known by its French name, Bureau International des Poids et Mesures (BIPM)).

The following terms, when used in the present Manual, have the meanings given below.

Accuracy. The extent to which the results of the readings of an instrument approach the true value of the calculated or measured quantities, supposing that all possible corrections are applied.

Acoustic Doppler current profiler (ADCP). A hydroacoustic device to measure the velocity of water over a range of depths in a column using the Doppler effect, with the overall depth of water usually being measured simultaneously.

Acoustic velocity meter. A system that uses the difference in travel time of acoustic (ultrasonic) pulses between transducers in a stream to determine the mean velocity on the signal path.

Actual time of observation: (a) In the case of a surface synoptic observation, the time at which the barometer is read; (b) In the case of upper-air observations, the time at which the balloon, parachute or rocket is actually released.

Adaptive maintenance. Modification of an instrument, software or other product, performed after installation to keep it usable in a changed or changing environment.

Aeronautical meteorological station. A station designated to make observations and meteorological reports for use in international air navigation.

Agricultural meteorological station. A station that provides meteorological data for agricultural and biological purposes, and makes other meteorological observations under programmes of agrometeorological research centres and other relevant organizations.

Aircraft Meteorological Data Relay (AMDAR). An automated system for the collection of aviation meteorological data from aircraft.

Aircraft meteorological station. See *Technical Regulations* (WMO-No. 49), Volume I.

Aircraft weather reconnaissance flights. An aircraft flight for the specific purpose of making observations.

Automatic station. An observing station at which instruments make and transmit observations, the conversion to code form for international exchange being made either directly or at an editing station.

Bank. (a) Rising land bordering a river, usually to contain the stream within the wetted perimeter of the channel; (b) Margin of a channel on the left-hand (right-hand) side when facing downstream.

BUFR. The Binary Universal Form for the Representation of meteorological data; a binary data format.

Cableway. A cable stretched above and across a stream, from which a current meter or other measuring or sampling device is suspended and moved from one bank to the other, at predetermined depths below the water surface.

Calibration (rating) tank (straight open tank). A tank containing still water through which a current meter is moved at a known velocity in order to calibrate the meter.

Catchment area. An area having a common outlet for its surface runoff.

Certification. The provision by an independent body of written assurance (a certificate) that the product, service or system in question meets specific requirements.

Climatological station. A station whose observations are used for climatological purposes.

Coastal station. An observing station on the coast that makes both surface land observations and surface marine observations.

Compliance. Adherence to an internal code of conduct where employees follow the principles of one of the quality management standards series (such as the ISO standards) or other internationally recognized practices and procedures. It could also be an external stamp of approval by an accreditation firm when customers or partners request documented proof of compliance.

Confidence level. Probability that the confidence interval includes the true value.

Control. Physical properties of a channel which determine the relationship between stage and discharge at a location in the channel.

Control structures. Artificial structures placed in a stream, such as a low weir or flume, to stabilize the stage-discharge relation, particularly in the low-flow range, where such structures are calibrated by stage and discharge measurements taken in the field.

Co-sponsored observing system. An observing system in which some but not all observations are WMO observations.

CryoNet. The core component of the WMO Global Cryosphere Watch (GCW) surface observing network.

CryoNet cluster. A component of CryoNet comprising two or more coordinated stations, of which at least one must be a CryoNet station or a CryoNet contributing station together with a station providing representative meteorological observations, and which together, meet the requirements for a CryoNet station.

CryoNet contributing station. A GCW station that provides useful measurements of the cryosphere but does not meet all requirements for a CryoNet station.

CryoNet station. A GCW station measuring at least one variable of one cryosphere component, and meeting a set of defined requirements.

Cross-section. A section perpendicular to the main direction of flow bounded by the free surface and wetted perimeter of the stream or channel.

Current meter. An instrument for measuring water velocity.

Current meter, propeller type. A current meter the rotor of which is a propeller rotating around an axis parallel to the flow.

Data archiving. Storage of data on a set of catalogued files which are held in some backup storage medium and not necessarily permanently online.

Data compatibility. The capacity for two systems to exchange data without having to be altered to do so and without any need for changes in data formats.

Data processing. Treatment of observational data until they are in a form ready to be used for a specific purpose.

Data quality objectives. Definition of the type, quality and quantity of primary data and derived parameters required to yield information that can be used to support decisions.

Discharge. Volume of water flowing through a river (or channel) cross-section per unit time.

Drainage basin. See **catchment area**.

Drifting buoy. A floating automatic station that is free to drift under the influence of wind and current.

Elevation. The vertical distance of a point or level, on or affixed to the surface of the ground, measured from mean sea level.

Flood. (a) A rise, usually brief, in the water level of a stream or water body to a peak from which the water level recedes at a slower rate; (b) A relatively high flow as measured by stage height or discharge.

Flood-proofing. Techniques for preventing flood damage in a flood-prone area.

Gauge boards (staff gauges). Graduated vertical scales, fixed to a staff or structure, on which the water level may be read.

Gauge datum. The vertical distance between the zero of a gauge and a certain datum level.

Gauging station. Location on a stream where measurements of water level and/or discharge are made systematically.

Global Climate Observing System (GCOS) Reference Upper-air Network (GRUAN) station. An upper-air station included in the network of stations specially selected and certified to provide long-term high-quality climate records.

Global Climate Observing System (GCOS) Surface Network (GSN) station. A land station included in the specially selected network of stations to monitor daily and large-scale climate variability on a global basis.

Global Climate Observing System (GCOS) Upper-air Network (GUAN) station. An upper-air station included in the specially selected global baseline network of upper-air stations to meet GCOS requirements.

Global Cryosphere Watch (GCW) affiliated network. A network of stations measuring at least one cryospheric variable, contributing to GCW in addition to CryoNet and CryoNet contributing stations.

Global Cryosphere Watch (GCW) station. A station that measures and reports one or more variables of one or more components of the cryosphere.

Hydrograph. A graph showing the variation in time of some hydrological data such as stage, discharge, velocity and sediment load.

Hydrological forecast. An estimation of the magnitude and time of occurrence of future hydrological events for a specified period and for a specified locality.

Hydrological observation. A direct measurement or evaluation of one or more hydrological elements such as stage, discharge and water temperature.

Hydrological observing station. A place where hydrological observations or climatological observations for hydrological purposes are made.

Hydrological warning. Emergency information on an expected hydrological event that is considered to be dangerous.

Hydrometric station. A station gathering data on one or more parameters of water in rivers, lakes or reservoirs, such as stage, streamflow, sediment transport and deposition, water temperature and other physical or chemical properties of water, and characteristics of ice cover.

Intercomparison. A formalized process to assess the relative performance of two or more systems (observing, forecasting, etc.).

Mobile sea station. A station aboard a mobile ship or an ice floe.

Moving-boat method. A method of measuring discharge that uses a boat to traverse the stream along the measuring section and continuously measure velocity, depth and distance travelled.

Quality. The degree to which a set of inherent characteristics fulfils requirements.

Quality assurance. That part of quality management focused on providing confidence that quality requirements will be fulfilled.

Quality control. That part of quality management focused on fulfilling quality requirements.

Quality management. The coordinated activities that direct and manage an organization with respect to quality.

Observing facility. An observing station or platform.

Planetary boundary layer. The lowest layer in the atmosphere, usually taken to be up to 1 500 m, in which meteorological conditions are affected significantly by the Earth's surface.

Planetary boundary-layer observation. An observation of the planetary boundary layer.

Present and past weather. The qualitative description of observable phenomena, at the time of observation or during a preceding period.

Note: Relevant observable phenomena in the atmosphere include precipitation, suspended or blowing particles, and other designated optical phenomena or electrical manifestations, as described in the *International Cloud Atlas: Manual on the Observation of Clouds and Other Meteors* (WMO-No. 407), the *Guide to Instruments and Methods of Observation* (WMO-No. 8) and, for aeronautical applications, in the *Technical Regulations* (WMO-No. 49), Volume II.

Radar wind profiler observation. See *Technical Regulations* (WMO-No. 49), Volume I.

Radar wind profiler station. See *Technical Regulations* (WMO-No. 49), Volume I.

Radiation station. A station at which observations of radiation are made:

(a) Principal radiation station. A radiation station whose observing programme includes at least the continuous recording of global solar radiation and sky radiation, and regular measurements of direct solar radiation;

(b) Ordinary radiation station. A radiation station whose observing programme includes at least the continuous recording of global solar radiation.

Radiosonde station. A station at which observations of atmospheric pressure, temperature and humidity in the upper air are made by electronic means.

Rating curve. A curve showing the relation between stage and discharge of a stream at a hydrometric station.

Recession. The period of decreasing discharge as indicated by the falling limb of a hydrograph starting from the peak.

Reference climatological station. A climatological station gathering data intended for the purpose of determining climatic trends.

Note: This requires long periods (not less than 30 years) of homogeneous records, where human-induced environmental changes have been and/or are expected to remain at a minimum. Ideally, the records should be of sufficient length to enable the identification of secular changes of climate.

Regional Basic Observing Network (RBON). A network of surface-based meteorological, hydrological and related observing stations/platforms defined and adopted by the relevant WMO regional association, or the Executive Council or the World Meteorological Congress.

Regional Meteorological Centre (RMC). A centre of the Global Data-processing and Forecasting System whose primary purpose is to issue meteorological analyses and prognoses on a regional scale.

Registration. Certification is very often referred to as registration in North America.

Research and special-purpose vessel station. A vessel making voyages for scientific research or marine monitoring purposes, which is recruited to make meteorological observations during the voyages.

Reservoir. A body of water, either natural or man-made, used for storage, regulation and control of water resources.

River. A large stream that serves as the natural drainage for a basin.

Sea station. A station situated at sea which makes surface marine observations. Sea stations include ships and stations on fixed or drifting platforms.

Note: Such a station may also make subsurface observations in accordance with Intergovernmental Oceanographic Commission (IOC) regulations.

Special report. A report made at a non-standard time of observation when specified conditions or changes of conditions occur.

Stage. See **water level**.

Stage-discharge relation. The relationship between water level and discharge for a river cross-section, which may be expressed as a curve, a table or an equation.

Standard time of observation (standard time). A time specified for making meteorological observations:

(a) Main standard times: 0000, 0600, 1200, 1800 UTC;

(b) Intermediate standard times: 0300, 0900, 1500 and 2100 UTC;

(c) Additional standard times: 0100, 0200, 0400, 0500, 0700, 0800, 1000, 1100, 1300, 1400, 1600, 1700, 1900, 2000, 2200, 2300 UTC.

Sunshine duration. The total time in one day during which the direct solar irradiance is equal to or more than the threshold value for bright sunshine (the threshold being 120 W m^{-2} of direct solar irradiance).

Surface land station, surface marine station. See *Technical Regulations* (WMO-No. 49), Volume I.

Surface observation, surface land observation, surface marine observation. See *Technical Regulations* (WMO-No. 49), Volume I.

Streamflow. A general term for water flowing in a watercourse.

Synoptic observation. A specified basic set of meteorological information collected at a standard time of observation.

Upper-air observation. See *Technical Regulations* (WMO-No. 49), Volume I.

Upper-air station. See *Technical Regulations* (WMO-No. 49), Volume I.

Uncertainty. An estimate of the range of values within which the true value of a variable lies.

Upstream. The direction from which a fluid is moving.

User observational requirements. Requirements for geophysical variables expressed in terms of six criteria: horizontal resolution, vertical resolution, observing cycle, timeliness, uncertainty and stability (where appropriate). For each of these criteria, three values are determined:

(a) The **goal** is an ideal requirement above which further improvements are not necessary;

(b) The **threshold** is the minimum requirement to be met to ensure that data are useful,

(c) The **breakthrough** is an intermediate level between **threshold** and **goal** which, if achieved, would result in a significant improvement for the targeted application.

Verification. The process of establishing the truth, accuracy or validity of something.

Water level. The elevation of the free water surface of a water body relative to a datum level.

Weather radar observation. See *Technical Regulations* (WMO-No. 49), Volume I.

Weather radar station. See *Technical Regulations* (WMO-No. 49), Volume I.

1. INTRODUCTION TO THE WMO INTEGRATED GLOBAL OBSERVING SYSTEM

1.1 PURPOSE AND SCOPE

1.1.1 The WMO Integrated Global Observing System (WIGOS) shall be a framework for all WMO observing systems and for WMO contributions to co-sponsored observing systems in support of all WMO Programmes and activities.

Note: The co-sponsored observing systems are the Global Climate Observing System (GCOS) and the Global Ocean Observing System (GOOS), which are joint undertakings of WMO and the Intergovernmental Oceanographic Commission (IOC) of the United Nations Educational, Scientific and Cultural Organization (UNESCO), the United Nations Environment Programme (UNEP) and the International Science Council (ISC).

1.1.2 The WMO Integrated Global Observing System shall facilitate the use by WMO Members of observations from systems that are owned, managed and operated by a diverse array of organizations and programmes.

1.1.3 The principal purpose of WIGOS shall be to meet the evolving requirements of Members for observations.

1.1.4 The interoperability (including data compatibility) of WIGOS component observing systems shall be achieved through their common utilization and application of internationally accepted standards and recommended practices and procedures. Data compatibility shall also be supported through the use of data representation standards.

1.2 WIGOS COMPONENT OBSERVING SYSTEMS

The component observing systems of WIGOS shall comprise the Global Observing System (GOS) of the World Weather Watch (WWW) Programme, the observing component of the Global Atmosphere Watch (GAW) Programme, the WMO Hydrological Observing System (WHOS) of the Hydrology and Water Resources Programme (HWRP) and the observing component of the Global Cryosphere Watch (GCW), including their surface-based and space-based elements.

Note: The above component systems include all WMO contributions to the co-sponsored systems, the Global Framework for Climate Services (GFCS) and the Global Earth Observation System of Systems (GEOSS).

1.2.1 The Global Observing System of the World Weather Watch

1.2.1.1 The Global Observing System shall be a coordinated system of observing networks, methods, techniques, facilities and arrangements for making observations on a worldwide scale, and shall be one of the main components of the World Weather Watch.

1.2.1.2 The purpose of GOS shall be to provide the meteorological observations from all parts of the globe that are required by Members for operational and research purposes through all WMO and co-sponsored programmes.

1.2.1.3 The Global Observing System shall consist of: (a) a surface-based subsystem composed of regional basic and other networks of stations and platforms; and
(b) a space-based subsystem composed of: (i) an Earth observation space segment;
(ii) an associated ground system for data reception, dissemination and stewardship; and
(iii) a user segment.

1.2.1.4 **The Global Observing System shall comply with the provisions specified in sections 1, 2, 3, 4 and 5 of this Manual.**

1.2.2 The observing component of the Global Atmosphere Watch

1.2.2.1 **The Global Atmosphere Watch shall be a coordinated system of observing networks, methods, techniques, facilities and arrangements encompassing the many monitoring activities and scientific assessments devoted to the investigation of the chemical composition and related physical characteristics of the atmosphere.**

Note: The GAW Programme has six focal areas: ozone, greenhouse gases, reactive gases, aerosols, ultraviolet (UV) radiation and total atmospheric deposition. The GAW stations, in addition to measuring one or more of the parameters related to these areas, may also measure ancillary variables such as radiation, radio nuclides and persistent organic pollutants.

1.2.2.2 **The purpose of GAW shall be to provide data and other information on the chemical composition and related physical characteristics of the atmosphere to support multiple applications, as defined in section 6, in all parts of the globe. This is intended to reduce environmental risks to society, meet the requirements of environmental conventions, strengthen capabilities to predict the state of climate, weather and air quality, and contribute to scientific assessments in support of environmental policy.**

1.2.2.3 **The observing component of GAW shall consist of a surface-based system comprising networks for the observation of specified variables, complemented by space-based observations.**

1.2.2.4 **The observing component of the GAW Programme shall be operated in accordance with the provisions specified in sections 1, 2, 3, 4 and 6 of this Manual.**

1.2.3 The WMO Hydrological Observing System

1.2.3.1 **The WMO Hydrological Observing System shall comprise hydrological observations.**

Note: The composition of WHOS will be provided in a future edition of the *Technical Regulations* (WMO-No. 49), Volume III: Hydrology.

1.2.3.2 **The WMO Hydrological Observing System shall expand to include other elements identified through the Rolling Review of Requirements (RRR) (described in section 2.2.4 and Appendix 2.3) at the national, regional and global levels.**

1.2.3.3 **The purpose of WHOS shall be to provide a fully WMO Information System (WIS)-compliant services-oriented framework linking hydrologic data providers and users through a hydrologic information system enabling data registration, discovery and access.**

1.2.3.4 **Members making their hydrological observations available through the WHOS shall comply with the provisions specified in sections 1, 2, 3, 4 and 7 of this Manual.**

Note: The *Technical Regulations* (WMO-No. 49), Volume III, the *Guide to Hydrological Practices* (WMO-No. 168), Volume I, the *Manual on Stream Gauging* (WMO-No. 1044), Volume I, and the *Manual on Flood Forecasting and Warning* (WMO-No. 1072) provide the necessary information to operate hydrological stations to the prescribed standards.

1.2.4 The observing component of the Global Cryosphere Watch

1.2.4.1 **The observing component of GCW shall be a coordinated system of observing stations and platforms, methods, techniques, facilities and arrangements encompassing monitoring activities and related scientific assessments of the cryosphere.**

1.2.4.2 **The purpose of the observing component of GCW shall be to provide observations and other information on the cryosphere, from the local to the global scale, and to improve understanding of its behaviour, interactions with other components of the Earth's system, and impacts on society.**

1.2.4.3 The GCW surface observing network and its core network, CryoNet, should lead the standardization and coordination of cryospheric observations among existing programmes and networks according to GCW best practices.

Note: In fulfilling this role, the GCW surface observing network will support the incorporation of cryospheric observations into shared data products and services.

1.2.4.4 **Members making cryospheric observations shall comply with the provisions specified in sections 1, 2, 3, 4 and 8 of this Manual.**

1.3 GOVERNANCE AND MANAGEMENT

1.3.1 Implementation and operation of WIGOS

1.3.1.1 **Members shall be responsible for all activities connected with the implementation and operation of WIGOS on the territory of their respective countries.**

1.3.1.2 Members should, as far as possible, use national resources for the implementation and operation of WIGOS but, where necessary and if so requested, assistance may be provided in part through:

(a) The WMO Voluntary Cooperation Programme (VCP);

(b) Other bilateral or multilateral arrangements and facilities including the United Nations Development Programme (UNDP), which should be used to the maximum extent possible.

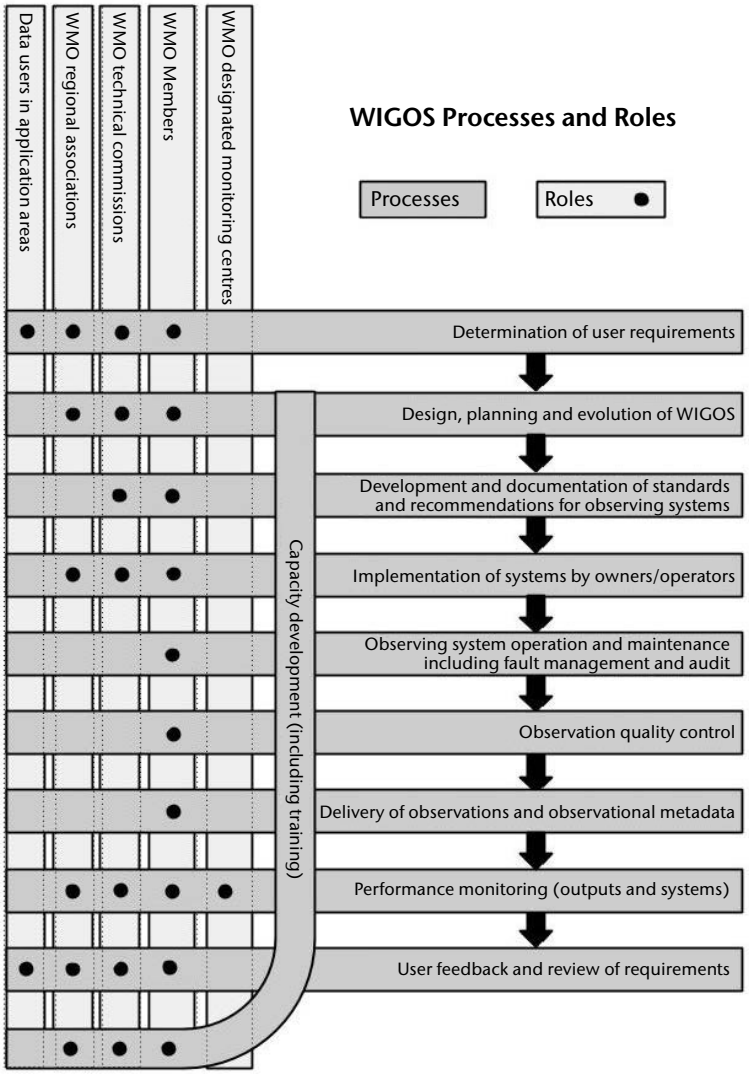
1.3.1.3 Members should participate voluntarily in the implementation and operation of WIGOS outside the territories of individual countries (for example, outer space, oceans and the Antarctic), if they wish and are able to contribute by providing facilities and services, either individually or jointly.

1.3.2 WIGOS quality management

Notes:
1. Within the WMO Quality Management Framework (QMF), WIGOS provides the procedures and practices regarding the quality of observations and observational metadata to be adopted by Members in establishing their quality management system for the provision of meteorological, hydrological, climatological and other related environmental observations.
2. Section 2.6 contains detailed provisions for WIGOS quality management.

1.3.3 WIGOS high-level processes

Members should adopt a process-based approach to the management of WIGOS as described in Attachment 1.1.


WIGOS Processes and Roles
Processes
Roles
Data users in application areas
WMO regional associations
WMO technical commissions
WMO Members
WMO designated monitoring centres
Determination of user requirements
Design, planning and evolution of WIGOS
Development and documentation of standards and recommendations for observing systems
Implementation of systems by owners/operators
Observing system operation and maintenance including fault management and audit
Observation quality control
Delivery of observations and observational metadata
Performance monitoring (outputs and systems)
User feedback and review of requirements
Capacity development (including training)

Schematic representation of WIGOS high-level processes

ATTACHMENT 1.1. WIGOS HIGH-LEVEL PROCESSES

Many of the WIGOS activities may be represented as a series of high-level processes.

The figure below provides a schematic description of the processes (horizontal bars), the collaborating entities (columns) and those primarily involved in each process (marked by solid circles). In reality, the processes have more complex interrelationships and sequences than shown by the arrows – the most extreme case being capacity development (including training) which is not shown as a step in the sequence since it provides important inputs to most of the other processes.

These processes are carried out by Members through one of the following modes of collaboration:

- Data users in application areas: Members collaborate by selectively contributing application experts and information;

- WMO regional associations: Members collaborate by working together in a geographical grouping and by selectively contributing experts for regional teams;

- WMO technical commissions: Members collaborate by selectively contributing technical experts for global teams;

- As individual operators and managers of observing systems, Members directly undertake the relevant WIGOS process(es);

- WMO designated centres for performance monitoring (including lead centres and monitoring centres): individual Members or groups of Members operate a WMO centre designated for performance monitoring.

In the case of WIGOS processes being undertaken by the WMO Secretariat or other entities funded by WMO Programmes, the mode of collaboration is through the overall operation of WMO.

The relationship between WIGOS high-level processes and the structure of the regulatory material is shown below: the standard and recommended practices and procedures relevant to each WIGOS process can be found in section 2, as indicated:

- Determination of user requirements: 2.1 and 2.2;

- Design, planning and evolution of WIGOS: 2.2;

- Development and documentation of standards and recommendations for observing systems: 2.3;

- Implementation of an observing system by owners and operators: 2.3 and 2.4;

- Observing system operation and maintenance, including fault management and audit: 2.4;

- Observation quality control: 2.4 and 2.6;

- Delivery of observations and observational metadata: 2.4 and 2.5;

- Performance monitoring: 2.4 and 2.6;

- User feedback and review of requirements: 2.2.4, 2.6.3.5 and Appendix 2.3;

- Capacity development (including training): 2.7.

2. COMMON ATTRIBUTES OF WIGOS COMPONENT SYSTEMS

2.1 USER REQUIREMENTS

2.1.1 Members shall take steps to collect, record, review, update and make available their user requirements for observations.

2.1.2 Members shall convey their user observational requirements, for each of the WMO application areas, to the RRR process described under section 2.2.4 and Appendix 2.3.

2.2 DESIGN, PLANNING AND EVOLUTION

2.2.1 General

2.2.1.1 Members shall design WIGOS as a flexible and evolving system capable of continuous improvement.

Note: Factors that drive the evolution of WIGOS component observing systems include technological and scientific progress and cost-effectiveness; changes in the needs and requirements of WMO, WMO co-sponsored programmes and international partner organizations at national, regional and global levels; and changes in the capacity of Members to implement observing systems. It is important to identify the impact on all users before a change is made.

2.2.1.2 Members shall plan and operate their networks in a sustainable and reliable manner using WIGOS standard and recommended practices and procedures, and tools.

Note: Sustainability over at least a ten-year period is recommended; however, this depends on paying sufficient attention to maintenance and operations following the establishment of the network.

2.2.2 Principles for observing network design and planning

2.2.2.1 *Observing network design principles*

2.2.2.1.1 Members should follow the principles specified in Appendix 2.1 when designing and developing their observing networks.

2.2.2.1.2 Members should conduct network design studies that address national, regional and global scale questions about the optimum affordable mix of components to best satisfy the requirements for observations.

2.2.2.2 *Climate monitoring principles of the Global Climate Observing System*

Members designing and operating observing systems for monitoring the climate should adhere to the principles specified in Appendix 2.2.

Note: Fifty-four Essential Climate Variables have been identified for GCOS. These are required to support the work of the United Nations Framework Convention on Climate Change (UNFCCC) and the Inter-governmental Panel on Climate Change (IPCC). The Essential Climate Variables cover the atmospheric, oceanic and terrestrial domains, and all are technically and economically feasible for systematic observation. Further information about the Essential Climate Variables can be found in *The Global Observing System for Climate: Implementation Needs* (GCOS-200).

2.2.2.3 *Observations in special circumstances*

Members should operate their observing systems with the capacity to adapt to and target the special requirements that arise under special circumstances.

Note: Several WMO application areas require specific observations under special circumstances. Attachment 2.1. provides further details of specific requirements in several special circumstances. Provisions relating to satellite rapid scans and other special observations also appear in subsequent sections of this Manual.

2.2.3 Vision for WIGOS

Members shall take into account the Vision for WIGOS in 2040 when planning the evolution of their observing networks.

Notes:

1. The Vision for WIGOS in 2040 provides high-level goals to guide the evolution of WIGOS in the coming decades. The Vision is updated on a multi-year timescale (typically decadal).
2. The Vision for WIGOS in 2040 is available at https://community.wmo.int/vision2040.

2.2.4 The Rolling Review of Requirements

Members, both directly and through the participation of their experts in the activities of regional associations and technical commissions, shall contribute to the RRR process and assist the designated Points of Contact for each application area in performing their roles in the RRR.

Note: Appendix 2.3 provides further details on the RRR process.

2.2.5 Observation impact studies

2.2.5.1 Members, or groups of Members within regions, should conduct or participate in observation impact studies and related scientific evaluations to address WIGOS network design questions.

2.2.5.2 Members should provide expertise for synthesizing the results of impact studies and making recommendations on the best mix of observing systems to address the gaps identified by the RRR process.

Note: Observing system experiments, observing system simulation experiments, studies of forecast sensitivity to observations, and other tools are used to assess the impact of the various observing systems on Numerical Weather Prediction model analyses and predictions, hence their value and relative priority for addition or retention in these application areas.

2.2.6 Evolution of WIGOS component observing systems

2.2.6.1 Members should follow the plans published by WMO for the evolution of WIGOS component observing systems when planning and managing their observing systems.

Notes:

1. The planning and coordination of the evolution of WIGOS component observing systems is steered by the Executive Council and undertaken by Members individually and through regional associations, technical commissions and the relevant steering bodies of WMO co-sponsored observing systems.
2. The current WMO plan for the evolution of WIGOS component observing systems was published as *Implementation Plan for the Evolution of Global Observing Systems (EGOS-IP)* (WIGOS Technical Report No. 2013-4). It contains guidelines and recommended actions to be undertaken by Members, technical commissions, regional

associations, satellite operators and other relevant parties in order to stimulate the cost-effective evolution of the WMO observing systems and address in an integrated way the requirements of WMO Programmes and co-sponsored programmes.

3. The WMO plan for the evolution of WIGOS observing systems is regularly updated and new versions are published on a multi-year timescale (typically decadal), taking into account the vision for the WIGOS component observing systems, the advice of the technical commissions and regional associations concerned, relevant WMO co-sponsored observing systems and international experts in all application areas.

2.2.6.2 **Members shall coordinate the activities of organizations within their territory, including National Meteorological and Hydrological Services (NMHSs), academia, research institutions, ministries of environment, ocean communities, and related agencies, in addressing relevant actions of WMO plans for the evolution of WIGOS observing systems.**

2.2.6.3 Where Members cover small areas and are geographically close or have already established multilateral working relationships, they should consider a subregional or transboundary river basin approach, in addition to a national one, in planning WIGOS observing systems.

2.2.6.4 In such cases, the Members concerned should work in close cooperation to prepare subregional or transboundary river basin reviews of requirements to be used as a basis for detailed planning at that scale.

2.2.7 Monitoring the evolution of WIGOS component observing systems

Members should contribute to the monitoring of the evolution of WIGOS component observing systems by providing their national progress reports on a yearly basis through nominated national focal points.

Note: The Commission for Observation, Infrastructure and Information Systems (INFCOM), in collaboration with the Commission for Weather, Climate, Water and Related Environmental Services and Applications (SERCOM) and the Research Board, regional associations, and co-sponsored programmes, regularly reviews progress in the evolution of WIGOS component observing systems and provides updated guidance to Members thereon.

2.3 INSTRUMENTATION AND METHODS OF OBSERVATION

2.3.1 General requirements

Note: Details are provided in the *Technical Regulations* (WMO-No. 49), Volume III, the *Guide to Instruments and Methods of Observation* (WMO-No. 8), and the *Guide to Hydrological Practices* (WMO-No. 168), Volume I.

2.3.1.1 **Members shall ensure that observations are traceable to the International System of Units (Système international d'unités (SI)) standards, where these exist.**

Notes:

1. Traceability to SI standards is an area where concerted effort is required to increase or improve compliance.
2. It is also desirable that observational metadata are similarly traceable wherever possible.

2.3.1.2 **Members shall use properly calibrated instruments and sensors that provide observations satisfying at least measurement uncertainties that meet the specified requirements, including for emerging technologies.**

Notes:

1. Achievable measurement uncertainty is specified in the *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume I, Chapter 1, 1.6.4.2, and Annex 1.A.
2. A number of operational, financial, environmental and instrumental issues may in some cases prevent the system from satisfying the specified requirements. The *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume I, Annex 1.A (see the column "Achievable measurement uncertainty") provides a list of the achievable and affordable measurement uncertainties that in some cases might not satisfy specified requirements.

3. The strategy for traceability assurance, *described in the Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume I, Annex 1.B, provides further guidance.

2.3.1.3 Members should describe uncertainty of observations and observational metadata as specified in the *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume I, Chapter 1, 1.6.

Notes:
1. The corresponding text from the *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume I, Chapter 1, 1.6, will be included as an appendix in a future edition of the present Manual.
2. The definition of uncertainty given in the *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume I, Chapter 1, 1.6, is consistent with the international standards approved by the International Committee for Weights and Measures (Comité international des poids et mesures (CIPM)).
3. The traceability chain within the GAW Programme is defined in the *WMO Global Atmosphere Watch (GAW) Implementation Plan: 2016–2023* (GAW Report No. 228).

2.3.1.4 Members should follow the definitions and specifications for the calculation of derived observations given in the WMO Technical Regulations.

Notes:
1. Further methods provided or referenced by the *Guide to Instruments and Methods of Observation* (WMO-No. 8) and the *Guide to Hydrological Practices* (WMO-No. 168), Volume I, could also be considered.
2. Such derivations can take many forms, for example, statistical processing of average or smooth values, or multivariate algorithm to determine streamflow discharge.
3. The corresponding text from the *Guide to Instruments and Methods of Observation* (WMO-No. 8) will be included as an appendix in a future edition of the present Manual.

2.4 OPERATIONS

2.4.1 General requirements

Note: Provision 2.4.1.1 of the *Technical Regulations* (WMO-No. 49), Volume I, Part I, applies.

2.4.1.1 WMO observing stations and platforms shall be uniquely identified by a WIGOS station identifier.

Note: The structure of WIGOS station identifiers is specified in Attachment 2.2.

2.4.1.2 Members shall issue WIGOS station identifiers for observing stations and platforms within their geographic area of responsibility that contribute to a WMO or co-sponsored programme, and shall ensure that no WIGOS station identifier is issued to more than one station.

Notes:
1. Members may issue WIGOS station identifiers for observing stations and platforms within their geographic area of responsibility that do not contribute to a WMO or co-sponsored programme, provided that the operator has committed to providing and maintaining WIGOS metadata.
2. For surface marine stations or sea stations contributing to the co-sponsored GOOS OceanOPS (formerly JCOMMOPS) is authorized to issue WIGOS station identifiers on behalf of Members when asked to do so.
3. In line with the regulations under the Antarctic Treaty System, Members are authorized to issue WIGOS station identifiers for the stations/platforms they operate in Antarctica.

2.4.1.3 Before issuing a WIGOS station identifier, Members should ensure that the operator of a station or platform has committed to providing and maintaining WIGOS metadata for that station or platform.

Notes:

1. A WIGOS station identifier may be issued by an entity with delegated authority (listed in Attachment 2.2) hereafter referred to as "WSI issuers", for observing stations that contribute to a WMO or co-sponsored programme on behalf of Members under the following circumstances (the relevant procedures are described in the *Guide to the WMO Integrated Global Observing System* (WMO-No. 1165)):
   1.1 When a WIGOS station identifier is required for a station or platform to support a WMO or co-sponsored programme and no Member is in a position to issue one, the Secretary-General may issue a WIGOS station identifier for that station or platform, using the "issuer of identifier" allocated to the Secretary-General, provided that the operator of the station or platform has committed to:
      (a) Providing WIGOS metadata;
      (b) Conforming to relevant Technical Regulations.
   1.2 When a WIGOS station identifier is required for a station or platform to support a WMO or co-sponsored programme and a Member is not able to issue one, the WSI issuer will issue a WIGOS station identifier for that station or platform, provided that its operator has committed to:
      (a) Providing WIGOS metadata;
      (b) Conforming to relevant Technical Regulations.
   1.3 When a WIGOS station identifier is requested by the operator of a station or platform that contributes to a WMO or co-sponsored programme and the Member concerned has neither issued the identifier nor provided a valid reason for non-issuance, the WSI issuer will issue an identifier provided that its operator has committed to:
      (a) Providing WIGOS metadata;
      (b) Conforming to relevant Technical Regulations.
2. In all cases of 1.1 to 1.3 above, where a WIGOS station identifier is issued by an authority other than the Permanent Representative of the respective Member with WMO of the country or territory in which the station is operating, the Permanent Representative of the respective Member with WMO will be informed in writing by the Secretary-General and will be given a period of no less than 30 days to reverse this assignment if they believe they have a valid reason for doing so.

2.4.1.4 Members shall make available to WMO the updated metadata each time a new WIGOS station identifier is issued.

2.4.1.5 Members shall operate their observing systems with properly calibrated instruments and adequate observing and measuring techniques.

Notes:

1. Detailed guidance on observing practices for meteorological observing systems and instruments is given in the *Guide to Instruments and Methods of Observation* (WMO-No. 8).
2. Detailed guidance on observing practices for hydrological observing systems and instruments is given in the *Guide to Hydrological Practices* (WMO-No. 168), Volume I, the *Manual on Flood Forecasting and Warning* (WMO-No. 1072) and the *Manual on Stream Gauging* (WMO-No. 1044), Volume I,.
3. Detailed guidance on observing practices for GAW observing systems and instruments is given in the *Guide to Instruments and Methods of Observation* (WMO-No. 8) and related measurements guidelines published as GAW Reports.

2.4.1.6 Members should address the requirements for uncertainty, timeliness, temporal resolution, spatial resolution and coverage that result from the RRR process specified in section 2.2.4, and in accordance with the details provided in other sections as appropriate.

2.4.1.7 Members shall ensure that proper safety procedures are specified, documented and followed in all their operations.

Note: Safety practices and procedures are intended to ensure the welfare of staff while promoting overall efficiency and effectiveness of the NMHS. Such practices and procedures conform to national laws, regulations and requirements for occupational health and safety.

2.4.2 Observing practices

Members should ensure that their observing practices comply with user observational requirements.

Note: Observing practices include station operation, data processing practices and procedures, applied calculation rules, documentation on calibration practices and associated metadata.

2.4.3 Quality control

2.4.3.1 Members shall ensure that observations provided through their WIGOS component observing systems are quality controlled.

2.4.3.2 Members shall implement real-time quality control prior to exchange of observations via the WMO Information System.

Notes:

1. Quality control of observations consists in the examination of observations at stations and data centres to detect errors so that they may be either corrected or flagged. A quality control system should include procedures for tracing the observations to their source to verify them and to prevent the recurrence of errors. Quality control is applied in real time, but it also operates in non-real time, as delayed quality control. The quality of observations depends on the quality control procedures applied during acquisition and processing of observations and during the preparation of messages, in order to eliminate the main sources of errors and ensure the highest possible standard of accuracy for the optimum use of those observations by all possible users.
2. Quality control in real time also takes place in the Global Data-processing and Forecasting System, prior to the use of meteorological and climatological observations in data processing (i.e. objective analysis and forecasting).
3. The *Guide on the Global Data-processing System* (WMO-No. 305) provides more detailed guidance.
4. The *Guide to the Global Observing System* (WMO-No. 488), Part VI, and the *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume III, Chapter 1, 1.5, and Volume V, Chapter 1, 1.7, provide guidance on quality control of surface observations.
5. Recommended practices and procedures for quality control of aircraft-based observations and specifications for quality control of on-board data can be found in the *Guide to Aircraft-based Observations (WMO-No. 1200), Appendices A and B, and in the AMDAR Onboard Software Functional Requirements Specification (*Instruments and Observing Methods, Report No. 115), Chapter 3.
6. Recommended practices and procedures for quality control of hydrological observations are given in the *Manual on Flood Forecasting and Warning* (WMO-No. 1072), Chapter 6, and in the *Guide to Hydrological Practices* (WMO-No. 168), Volume I.
7. Recommended practices and procedures regarding the quality of observations for GAW requirements are formulated in measurement guidelines through data quality objectives available under GAW Programme Reports at https://community.wmo.int/gaw-reports.

2.4.3.3 Members not capable of implementing these standards should establish agreements with an appropriate Regional Meteorological Centre or World Meteorological Centre to perform the necessary quality control.

2.4.3.4 Members shall also perform quality control of observations on a non-real-time basis, prior to forwarding the observations for archiving.

2.4.3.5 Members should develop and implement adequate quality control processes.

Notes:

1. Quality control processes include (but are not necessarily limited to): (a) validation; (b) cleaning and (c) monitoring.
2. Further guidance is available in the *Guide to Instruments and Methods of Observation* (WMO-No. 8), the *Guide to Climatological Practices* (WMO-No. 100), the *Guide to Hydrological Practices* (WMO-No. 168), Volume I, and the *Guide to the Global Observing System* (WMO-No. 488), Part VI.

2.4.4 Data and metadata reporting

Note: Members are to report and make available up-to-date WIGOS metadata as specified in section 2.5.2.

2.4.4.1 Members shall report and make available observations in real time through the WMO Information System (WIS) in the standard formats specified by the *Manual on Codes* (WMO-No. 306), Volumes *I.1*, *I.2* and *I.3*.

Note: This provision also applies to associated metadata provided in real time when it is part of the standard format.

2.4.4.2 Members shall use the International System of Units.

Notes:
1. Further information is available at www.bipm.org/en/measurement-units/.
2. Detailed guidance is given in the *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume I, Chapter 1, 1.5.

2.4.4.3 When observing and reporting atmospheric pressure for meteorological purposes, Members shall use the hectopascal (hPa).

2.4.4.4 When observing and reporting air temperature for meteorological purposes, Members shall use the degree Celsius.

2.4.4.5 In the case of GAW observations, Members shall report and make observations available in standard formats as advised by World Data Centres, in accordance with the provisions laid out in Chapter 6.

2.4.4.6 Members shall record, retain and archive all observations they make available internationally.

Note: Non-destructive storage of observations is important to ensure that data and metadata quality and information content are not altered.

2.4.4.7 Members should record and retain all Level I data used when making observations available internationally.

2.4.5 Incident management

2.4.5.1 Members should implement incident management to detect, identify, record, analyse and respond to any incident, in order to restore normal operation of the observing system as quickly as possible, minimizing the negative impact and preventing recurrence.

2.4.5.2 Members shall implement procedures to detect, analyse and respond to system issues and human errors at the earliest stage possible.

Notes:
1. Some incidents, such as internal problems within the observing systems, may be detected automatically and reported without delay to international recipients of observations. Other incidents may be detected with delay or through periodic checks and reported accordingly.
2. Automatic incident detection can be performed using either built-in test equipment or external monitoring systems.
3. A centralized system can help monitor the performance and health of automatic weather station (AWS) systems and networks.

2.4.5.3 Members should record and analyse incidents as appropriate.

2.4.5.4 Members should provide incident information in accordance with 2.5 in real time.

Note: Such reporting in real time will be feasible when a corresponding WMO format is available.

2.4.5.5 Members should respond to incidents raised by the WIGOS Incident Management Function.

Notes:
1. The WIGOS Incident Management Function is to be operated by designated global centres and Regional WIGOS centres.
2. The WIGOS Data Quality Monitoring System (WDQMS) is described in Attachment 2.4.
3. Further guidance on WDQMS is provided by the *Guide to the WMO Integrated Global Observing System* (WMO-No. 1165)

2.4.5.6 Members who exchange observations internationally should report any major incidents they detect to international recipients of observations, and should state when such incidents have been resolved.

2.4.6 Change management

2.4.6.1 Members should carefully plan and manage changes to ensure continuity and consistency of observations, and should record any modification related to the observing system.

Notes:
1. This requirement relates to any change in the observing system, including an observing station, observing programme, instruments, methods of observation and so on.
2. When changes are made, relevant metadata are to be updated in accordance with section 2.5.

2.4.6.2 When making changes to the observing system, Members should notify national and international stakeholders and observation users in advance.

Notes:
1. These notifications include information on the expected impacts and the time period over which the change will take place and, importantly, when the change is complete.
2. The record of changes includes the nature and characteristics of the change, the date and time of implementation and the reason for making the change.

2.4.6.3 In the event of significant changes in instruments or methods of observation used or the location in which observations are made, Members should ensure a sufficiently long period (to capture all expected climatic conditions) of overlap, with dual operation of old and new systems to identify biases, inconsistencies and inhomogeneities.

2.4.7 Maintenance

2.4.7.1 Members shall ensure that each observing system is rigorously maintained.

2.4.7.2 Members shall perform regular preventive maintenance of their observing systems including instruments.

Notes:
1. Carefully organized preventive maintenance of all system components is recommended to minimize corrective action and to increase the operational reliability of an observing system.
2. To minimize disruption to users, Members may provide advanced notice and discuss suitable timing.

2.4.7.3 Members shall determine the frequency and timing (schedule) of the preventive maintenance taking into account the type of observing system, environmental and climate conditions of the observing site and platform, and the instrumentation installed.

2.4.7.4 **Members shall perform corrective maintenance in the event of failure of an observing system component as soon as practically possible once the issue has been detected.**

Note: The assessment of what is practically possible may take into account the severity of the issue.

2.4.7.5 **Members shall employ adaptive maintenance that satisfies the requirements for stability, continuity and consistency of observations through time.**

2.4.7.6 Members should consider any maintenance activity that reduces data availability and quality as an incident.

2.4.7.7 Members should flag, remove or not report, as appropriate, observations that are adversely affected by maintenance activities.

Note: Detailed guidance on maintenance of observing systems and instruments is given in the *Guide to Instruments and Methods of Observation* (WMO-No. 8), including technical papers on GAW measurements referenced in Volume I, Chapter 16; the *Guide to Hydrological Practices* (WMO-No. 168), Volume I, and the *Manual on Stream Gauging* (WMO-No. 1044), Volume I,.

2.4.8 Inspection

Members shall arrange periodic inspections of their observing systems with the frequency and timing (schedule) adequate for the type of observing system, environmental and climate conditions of the observing site and platform, and the instrumentation installed.

Notes:
1. Such inspections could be undertaken on site or remotely, as necessary, to monitor the correct functioning of observing platforms and instruments.
2. Further guidance is available in the *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume I, Chapter 1, 1.3.5; Volume III, Chapter 1, 1.7; and Volume V, Chapter 1, 1.10.1, and Chapter 4, 4.3.4; the *Guide to Climatological Practices* (WMO-No. 100), 2.3.5 and 2.6.6; the *Guide to Hydrological Practices* (WMO-No. 168), Volume I, 9.8.4; and the *Guide to the Global Observing System* (WMO-No. 488), 3.1.3.8.

2.4.9 Calibration procedures

2.4.9.1 **Members shall ensure that measurement systems and instruments are calibrated regularly in accordance with adequate procedures for each type of system and instrument, as described in the relevant sections of the present Manual.**

Notes:
1. Where international or national standards are not available, the basis for calibration is defined or supplied by the manufacturer or by the scientific advisory groups for GAW observations.
2. Detailed guidance on calibration procedures is given in the *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume V, Chapter 4, the *Guide to Hydrological Practices* (WMO-No. 168), Volume I, and the *Manual on Stream Gauging* (WMO-No. 1044), Volume I.
3. In the GAW Programme, World Calibration Centres perform the audit of the stations and organize network-wide comparison campaigns, and require that every laboratory is traceable to the single network standard.

2.4.9.2 **Members shall ensure that the measuring devices they use are:**

(a) Calibrated or verified at specified intervals, or prior to use, against measurement standards traceable to international or national standards. Where no such standards exist, the method used for calibration or verification is to be recorded;

(b) Adjusted or readjusted as necessary, but at the same time safeguarded from adjustments that would invalidate the measurements;

(c) Identified, enabling the calibration status to be determined;

(d) Protected from damage and deterioration during handling, maintenance and storage.

Note: Details regarding hydrological observations are given in the *Technical Regulations* (WMO-No. 49), Volume III; guidance is available in the *Guide to Instruments and Methods of Observation* (WMO-No. 8), the *Guide to Hydrological Practices* (WMO-No. 168), Volume I, and the *Manual on Stream Gauging* (WMO-No. 1044), Volume I.

2.4.9.3 **When the equipment is found not to conform to requirements, the Member shall assess and record the validity of previous measuring results and take appropriate action on the equipment and the products affected.**

2.4.9.4 **Members shall record and maintain the results of calibration and verification.**

2.4.9.5 Members should consider any calibration or verification activity that reduces data availability and quality as an incident.

2.4.9.6 Members should flag, remove or not report, as appropriate, observations that are adversely affected by calibration or verification activity.

2.5 OBSERVATIONAL METADATA

2.5.1 Purpose and scope

Notes:
1. Observational metadata are essential as they enable users to assess the suitability of observations for the intended application, and managers of observing systems to monitor and control their systems and networks. Members benefit from sharing observational metadata which describe the quality of observations and provide information about stations and networks used to collect such observations.
2. Discovery metadata, defined in the *Manual on the WMO Information System* (WMO-No. 1060), are concerned with discovering and accessing information, including observations and their observational metadata. Requirements for discovery metadata are specified in the *Manual on the WMO Information System* and are not considered further here.

2.5.1.1 **For all WIGOS observations they make available internationally, Members shall record and retain the observational metadata specified as mandatory in Appendix 2.4 and in the *WIGOS Metadata Standard* (WMO-No. 1192).**

Notes:
1. The *WIGOS Metadata Standard* (WMO-No. 1192) defines a common set of requirements for observational metadata. It includes a detailed list of mandatory, conditional and optional metadata.
2. "Not available", "unknown" or "not applicable" are valid values for many elements of the WIGOS Metadata Standard. These terms assist Members in achieving compliance with the standard, particularly while developing the capability to report actual values.

2.5.1.2 **For all WIGOS observations they make available internationally, Members shall record and retain the observational metadata specified as conditional in Appendix 2.4 and in the *WIGOS Metadata Standard* (WMO-No. 1192) whenever the related condition is met.**

2.5.1.3 For all WIGOS observations they make available internationally, Members should record and retain the observational metadata specified as optional in Appendix 2.4 and in the *WIGOS Metadata Standard* (WMO-No. 1192).

2.5.1.4 For all WIGOS observations they make available internationally, Members should consider recording and retaining observational metadata that is additional to that specified in the *WIGOS Metadata Standard* (WMO-No. 1192).

Notes:
1. Such additional metadata are to be considered if they help users to interpret the observations or if they help operators to manage observing systems.
2. Some observational metadata do not change or change very infrequently compared to the observing cycle of the station/platform to which they relate. Such metadata, sometimes referred to as static metadata, can generally be made available through the database of the Observing Systems Capability Analysis and Review (OSCAR) tool, which is described in Attachment 2.3, but they must be monitored and updated in the OSCAR database when they change. Some observational metadata change with each new observation or quite often compared to the observing cycle. Such metadata, sometimes referred to as dynamic metadata, need to be made available as a stand-alone dataset or with the associated observations if an appropriate reporting format is available.
3. Some further requirements for observational metadata beyond the WIGOS Metadata Standard are stated in the following sections.
4. Further guidance on metadata and sound metadata practices is provided in the *Guide to the WMO Integrated Global Observing System* (WMO-No. 1165) and other Guides and specific documentation associated with the individual observing system components.

2.5.2 Exchanging and archiving observational metadata

2.5.2.1 Members shall make available internationally, without restriction, those mandatory and conditional (whenever the condition is met) observational metadata that support the observations made available internationally.

2.5.2.2 Members making observations available internationally shall retain and make available, without restriction, observational metadata for at least as long as they retain the observations described by the observational metadata.

2.5.2.3 Members making available internationally archived observations shall ensure that all WIGOS metadata describing the observations remain available, without restriction, for at least as long as the observations are retained.

2.5.2.4 Members making available internationally archived observations should ensure that any additional observational metadata describing the observations remain available, without restriction, for at least as long as the observations are retained.

2.5.3 Global compilation of observational metadata

2.5.3.1 Members shall make available to WMO for global compilation those components of the WIGOS metadata that are specified as mandatory or conditional (whenever the condition is met).

Note: Global compilations of WIGOS metadata are held in several databases. The OSCAR database of the WIGOS Information Resource (WIR) is the key source of information for WIGOS metadata. Other global compilations of specific components of WIGOS metadata include elements of the GAW Station Information System (GAWSIS), the OceanOPS database and others. Purpose and management of WIR and OSCAR are described in Attachment 2.3.

2.5.3.2 For all WIGOS component observing systems they operate, Members shall provide the required WIGOS metadata to keep the relevant databases of WMO observational metadata up to date.

2.5.3.3 Members shall routinely monitor the content of databases of WIGOS metadata and shall make all necessary changes in order to keep the databases up-to-date and accurate.

Note: Members may wish to consult with the WMO Secretariat when undertaking these activities.

2.5.3.4 **Members shall designate their national focal points responsible for making available metadata and for monitoring the content of databases of WMO observational metadata, and shall inform the Secretariat accordingly.**

2.5.3.5 **Members delegating to a global or regional entity the responsibility of the national focal point for all or part of the observing networks they operate shall inform the Secretariat accordingly.**

2.6 QUALITY MANAGEMENT

Notes:

1. Detailed guidance on how to develop and implement a quality management system (QMS) to ensure and enhance the quality of products and services of NMHSs is provided in the *Guide to the Implementation of Quality Management Systems for National Meteorological and Hydrological Services and Other Relevant Service Providers* (WMO-No. 1100).
2. The definitions, terminology, vocabulary and abbreviations used in relation to quality management are those of the International Organization for Standardization (ISO) 9000 family of standards for quality management systems, in particular *ISO 9000:2015, Quality Management Systems – Fundamentals and vocabulary*.
3. A QMS can be implemented only by the body that has the resources and the mandate to manage the observing system. According to the WMO QMF, Members are urged to follow the standard and recommended practices and procedures associated with the implementation of a QMS. In practice, however, it is one or more organizations within the Member country that own and operate observing systems and provide observations and observational metadata, most notably the NMHSs. Therefore, implementation of the WMO QMF relies on the Member making arrangements for such organizations to implement a QMS.
4. In this section, the term "observations" includes also observational metadata.

2.6.1 Scope and purpose of WIGOS quality management

Note: The practices and procedures of WIGOS enable Members to comply with the WMO QMF in relation to the quality of observations.

2.6.2 WIGOS component of the WMO Quality Management Framework

2.6.2.1 *Quality policy*

2.6.2.1.1 In the establishment and maintenance of WIGOS component observing systems, Members should ensure optimum affordable quality for all observations.

2.6.2.1.2 Members should, through a process of continual improvement, pursue effective and efficient management and governance of observing systems.

2.6.2.2 *Application of the eight principles of quality management*

Members should apply the eight principles of quality management to the implementation of WIGOS, as specified in Appendix 2.5.

2.6.3 WIGOS quality management processes

Note: The processes and roles of various entities are described in Attachment 1.1.

2.6.3.1 *Determination and maintenance of user requirements*

Note: The WMO RRR process for compiling user observational requirements is described in section 2.2.4 and Appendix 2.3.

2.6.3.2 *Development and documentation of observing system standards and recommendations*

Through involvement in the work of technical commissions, Members should participate in the development of observing system standard and recommended practices and procedures.

2.6.3.3 *Training of personnel and capacity development*

Members should ensure appropriate planning and implementation of training and capacity development activities.

2.6.3.4 *Performance monitoring*

2.6.3.4.1 Members should use and respond to the results, advice and reports of designated monitoring centres and any subsequent advice of expert groups.

2.6.3.4.2 Members should use and respond to the outputs from WIGOS Quality Monitoring and Evaluation Functions.

Notes:
1. The WIGOS Quality Monitoring and Evaluation Functions are to be carried out by designated global and Regional WIGOS Centres.
2. Existing lead and monitoring centres can be recognized as having a WIGOS Quality Monitoring and/or Evaluation Function, hence they can identify issues for the attention of Members.
3. Further guidance on WDQMS is provided by the *Guide to the WMO Integrated Global Observing System* (WMO-No. 1165).

2.6.3.5 *Feedback, change management and improvement*

2.6.3.5.1 Members should ensure that issues and incidents identified by the WIGOS Data Quality Monitoring System Functions are rectified in a timely manner and that a process for their documentation and rectification is implemented and maintained.

Note: Existing lead and monitoring centres can be recognized as having a WIGOS Quality Monitoring and/or Evaluation Function, hence they can identify issues for the attention of Members.

2.6.3.5.2 Upon identification or notification of issues and incidents related to the quality of observations, Members should analyse the issue detected and make the necessary improvements to operational practices and procedures so as to minimize the adverse impacts of those issues and incidents and prevent their recurrence.

2.6.3.5.3 Members should ensure that changes to operational practices and procedures are documented accordingly.

2.6.4 WIGOS aspects of development and implementation of the quality management system of Members

Note: This section specifies requirements for the integration of WIGOS practices and procedures into the QMS of Members. The requirements are based on the eight clauses of the ISO 9001 standard. The *Guide to the Implementation of Quality Management Systems for National Meteorological and Hydrological Services and Other Relevant Service Providers* (WMO-No. 1100) provides extensive explanatory notes about the eight clauses. The five subsections that follow correspond to the last five of those clauses, providing further details about the elements required in a QMS.

2.6.4.1 *General requirements for the content of a quality management system*

Members should identify their high-level processes and interactions that lead to the provision of observations.

Note: In addition to WIGOS specific provisions, there are many other general requirements for the content of a QMS that are not unique to WIGOS observations, hence they are not repeated here.

2.6.4.2 *Requirements related to management and planning*

2.6.4.2.1 Members should clearly demonstrate and document their commitment to the integration of WIGOS quality management practices within their QMS.

2.6.4.2.2 Members should carefully identify and routinely review user requirements for observations prior to attempting to meet user needs.

2.6.4.2.3 Members should ensure that their published quality policy is consistent with the WIGOS quality policy.

2.6.4.2.4 Members should establish and indicate the objectives for the observations they intend to provide in the future in order to guide stakeholders, users and clients with regard to the expected evolution of and changes to the observing systems they operate as a contribution to WIGOS.

Note: The objectives referred to in this provision constitute the WIGOS quality objectives.

2.6.4.2.5 Members should appoint a quality manager.

2.6.4.3 *Requirements related to resource management*

2.6.4.3.1 Members should determine and provide the resources needed to maintain and continuously improve the effectiveness and efficiency of their processes and procedures.

2.6.4.3.2 Members should define the competencies required of staff involved in the provision of observations.

2.6.4.3.3 Members should take steps to rectify any competency shortcomings identified for new or existing employees.

2.6.4.3.4 Members should implement policies and procedures to maintain the infrastructure required for the provision of observations.

2.6.4.4 *Requirements related to the provision of observations*

2.6.4.4.1 Members should undertake sound planning for the provision of observations.

Note: Such planning includes the following:

(a) Determination and continuous review of user and client requirements;
(b) Translation of user and client requirements into objectives and targets for observations and observing system design;
(c) Initial and ongoing allocation of adequate resources for all aspects of the design, implementation and maintenance processes of observing systems;
(d) Implementation of design processes and activities, including communication strategies and risk management, that will ensure the development and implementation of observing systems capable of meeting the design objectives and user and client requirements;
(e) Appropriate and ongoing documentation of planning processes and their results.

2.6.4.4.2 Members should identify the users of their observing systems and establish and document user requirements for observations.

Note: This involves:
(a) The WMO RRR process, described in section 2.2.4 and Appendix 2.3;
(b) Other processes to establish user requirements within WMO Programmes through the activities of WMO technical commissions;
(c) Regional processes through the activities of WMO regional associations and other multilateral groupings of Members;
(d) National processes.

2.6.4.4.3 Members should have a clear description of the requirements that have been agreed upon.

Note: It is important to note the difference between aspirational requirements and agreed requirements. The establishment of requirements provides essential information for the monitoring and measurement of conformance.

2.6.4.4.4 Members should identify and adhere to any statutory or regulatory requirements in relation to the provision of observations.

2.6.4.4.5 Members should design and develop, or otherwise implement, observing systems to satisfy the agreed user requirements.

2.6.4.4.6 Members should use a formal change management process to ensure that all changes are assessed, approved, implemented and reviewed in a controlled manner.

2.6.4.4.7 Members should conduct purchasing in a controlled manner.

Note: Observing systems are highly specialized and often require major expenditure. Staff responsible for purchasing orders or for providing information to suppliers must, therefore, ensure that the information and specifications provided are clear, unambiguous and based on the design objectives and system requirements to enable the delivery of the appropriate products and services. Purchasing in a controlled manner entails the following:
(a) Written specification of all performance requirements for equipment and/or services;
(b) Ensuring that purchasing is subject to a competitive process of more than one candidate for supply of equipment or services;
(c) Assessment of candidates for supply of equipment or services based on merit and suitability for purpose, which can be discerned from:
    (i) Written tendering or quotation of candidates;
    (ii) Experience or reliable anecdotal evidence of past performance;
    (iii) Recommendation of a Member or a recognized organization or agency;
(d) Documentation of the purchasing process and outcomes.

2.6.4.4.8 Members should include in their QMS the WIGOS provisions covering methods of observation, calibration and traceability, operational practices, maintenance and observational metadata.

2.6.4.4.9 Members should implement practices and procedures ensuring that observations remain accurate.

Notes:
1. Observations need to be checked as they must meet the agreed requirements. The methods used include automated algorithms, manual inspection and oversight.
2. Outputs available from WIGOS quality monitoring, evaluation and incident management functions are also to be integrated into such practices and procedures.

2.6.4.5 *Requirements for monitoring, performance measurement, analysis and improvement*

2.6.4.5.1 Members should use the agreed user requirements for observations (see 2.6.4.4) as a basis for defining and implementing appropriate measures of performance and success.

Notes:
1. It is important to gain a clear understanding of how satisfied users are with observations. This requires the monitoring of information on users' perception and on whether their expectations have been met. Surveys are commonly used for this purpose.
2. The WDQMS monitoring and evaluation thresholds, which trigger issues and incidents to be raised with Members through the incident management function, are based on agreed-upon user requirements.

2.6.4.5.2 Members should implement activities to obtain information on the satisfaction of users of observations.

2.6.4.5.3 Members should ensure that staff are made aware of the methods employed for determining users' perceptions and expectations, and that those methods are applied consistently.

2.6.4.5.4 Members should regularly conduct internal audits of WIGOS processes and procedures, and analyse the results as part of the management processes of the observing system.

Note: A detailed explanation of the requirements of the internal audit is provided in the *Guide to the Implementation of Quality Management Systems for National Meteorological and Hydrological Services and Other Relevant Service Providers* (WMO-No. 1100), Chapter 4, section 4.5, clause 9, requirement 9.2.

2.6.4.5.5 Members should monitor the degree of adherence to the defined processes and requirements for producing observations.

Note: Ideally, performance monitoring will be conducted against specific key performance indicators and target levels of performance.

2.6.4.5.6 Members should monitor and measure the suitability and the quality of their observations as they are produced, in order to compare their characteristics with the agreed requirements.

Note: This involves:
(a) The devising, implementation and routine analysis of manually or automatically generated key performance indicators and their associated targets;
(b) Manual inspection and oversight of the observational data produced.

2.6.4.5.7 Members should use the outputs from the WIGOS Quality Monitoring, Evaluation and Incident Management Functions for monitoring and confirming the suitability and quality of their observations.

2.6.4.5.8 Members should record instances of non-conformance with requirements, and endeavour to rectify issues and incidents in a timely manner.

Note: The Incident Management Function of the WDQMS can assist Members in identifying instances of non-conformance with requirements.

2.6.4.5.9 Members should maintain a documented corrective action procedure relevant to observations.

2.6.4.5.10 Members should specify and implement procedures that describe how non-conforming observations or observational metadata are identified, how they are dealt with, who is responsible for deciding what to do, what action should be taken and what records are to be kept.

Note: A detailed explanation of the requirements for corrective action is provided in the *Guide to the Implementation of Quality Management Systems for National Meteorological and Hydrological Services and Other Relevant Service Providers* (WMO-No. 1100), Chapter 4, section 4.5, clause 10, requirements 10.2.

2.6.4.5.11 Members should analyse monitoring results to detect any performance-related changes, trends and deficiencies and should use the results and analyses as input for continual improvement.

Notes:
1. Analysing trends and taking action prior to the occurrence of a case of non-conformance helps to prevent problems.
2. Careful analysis of trends is essential to differentiate between equipment drift and a physical change of the physical parameter.

2.6.4.5.12 Members should use the outputs from the WIGOS Quality Monitoring, Evaluation and Incident Management Functions as input for continual improvement.

2.6.4.5.13 Members should maintain documented preventive action procedures relevant to observing systems, and should ensure that staff are aware of and, if necessary, trained in their routine application.

Note: Due consideration might be given to combining the preventive and the corrective procedures for efficiency, and to simplify the process.

2.6.5 Compliance, certification and accreditation

Note: While WMO encourages the certification of Members' quality management systems by accredited agencies, unless otherwise required of a particular WIGOS component system or subsystem, there is no general regulated requirement for certification of QMS for WIGOS component observing systems.

2.6.6 Documentation

2.6.6.1 Members should include the WIGOS quality policy (2.6.2.1) and objectives (2.6.4.2) in their QMS quality manual.

2.6.6.2 Members should include in their QMS documentation those documents that describe the procedures related to WIGOS, including, in particular, those relating to control of non-conforming observations, and corrective and preventive actions.

2.6.6.3 Members should include in their QMS documentation those documents that describe the procedures required to ensure the effective planning, operation and control of their WIGOS processes.

2.6.6.4 Members should include in their QMS documentation those records required by the ISO 9001 standard.

Note: More detailed information on documentation requirements is provided in the *Guide to the Implementation of Quality Management Systems for National Meteorological and Hydrological Services and Other Relevant Service Providers* (WMO-No. 1100), Chapter 4, section 4.5, clause 4, requirement 4.4.

2.7 CAPACITY DEVELOPMENT

2.7.1 General

2.7.1.1 Members should identify their needs for capacity development in all activity areas of WIGOS.

2.7.1.2 Members should develop plans to meet their capacity development needs.

Note: In addition to national resources allocated to NMHSs, support may be available from other domestic agencies, the WMO regional association concerned, other Members through bilateral or multilateral arrangements, and WMO Programmes (including appropriate technical commissions).

2.7.1.3 Members should establish bilateral and multilateral collaboration (within and beyond their region) where necessary to address capacity development needs.

2.7.1.4 When planning capacity development activities, Members should take a holistic approach considering institutional, infrastructural, procedural and human resource requirements to support both current and continuing needs for installation, operation, maintenance, inspection and training. For this purpose, Members should prepare specific capacity development plans with measurable objectives to enable effective implementation, monitoring and assessment.

Note: Funds to meet these requirements should be planned well ahead, subject to national policies of Members, to assure long-term sustainable networks.

2.7.2 Training

2.7.2.1 **Members shall provide adequate training for their staff or take other appropriate action to ensure that all staff are suitably qualified and competent for the work assigned to them.**

Note: This requirement applies both to initial recruitment or introductory training and to continuing professional development.

2.7.2.2 Members should ensure that the qualifications, competencies, skills (and thus, training) and numbers of their personnel or other contractors match the range of tasks to be performed.

2.7.2.3 Members should inform the staff of their role and how they contribute to the achievement of the quality objectives.

2.7.3 Infrastructural capacity development

Members should regularly review their infrastructure for collecting and making available observations and observational metadata and should develop, as necessary, prioritized plans and priorities for capacity development.

APPENDIX 2.1. OBSERVING NETWORK DESIGN PRINCIPLES

1. **Serving many application areas**

Observing networks should be designed to meet the requirements of multiple application areas within WMO and WMO co-sponsored programmes.

2. **Responding to user requirements**

Observing networks should be designed to address stated user requirements, in terms of the geophysical variables to be observed and the space-time resolution, uncertainty, timeliness and stability needed.

3. **Meeting national, regional and global requirements**

Observing networks designed to meet national needs should also take into account the needs of WMO at the regional and global levels.

4. **Designing appropriately spaced networks**

Where high-level user requirements imply a need for spatial and temporal uniformity of observations, network design should also take account of other user requirements, such as the representativeness and usefulness of the observations.

5. **Designing cost-effective networks**

Observing networks should be designed to make the most cost-effective use of available resources. This will include the use of composite observing networks.

6. **Achieving homogeneity in observational data**

Observing networks should be designed so that the level of homogeneity of the delivered observational data meets the needs of the intended applications.

7. **Designing through a tiered approach**

Observing network design should use a tiered structure, through which information from reference observations of high quality can be transferred to other observations and used to improve their quality and utility.

8. **Designing reliable and stable networks**

Observing networks should be designed to be reliable and stable.

9. **Making observational data available**

Observing networks should be designed and should evolve in such a way as to ensure that the observations are made available to other WMO Members, at space-time resolutions and with a timeliness that meet the needs of regional and global applications.

10. Providing information so that the observations can be interpreted

Observing networks should be designed and operated in such a way that the details and history of instruments, their environments and operating conditions, their data processing procedures and other factors pertinent to the understanding and interpretation of the observational data (i.e. metadata) are documented and treated with the same care as the data themselves.

11. Achieving sustainable networks

Improvements in the sustained availability of observations should be promoted through the design and funding of networks that are sustainable in the long term including, where appropriate, through the transition of research systems to operational status.

12. Managing change

The design of new observing networks and changes to existing networks should ensure adequate consistency, quality and continuity of observations during the transition from the old system to the new.

APPENDIX 2.2. CLIMATE MONITORING PRINCIPLES OF THE GLOBAL CLIMATE OBSERVING SYSTEM

2.2.1 Effective monitoring systems for climate should adhere to the following principles:

(a) The impact of new systems or changes to existing ones should be assessed prior to implementation;

(b) A suitable period of overlap between new and old observing systems is required. This would be a period of dual operation, under the same climatic conditions, of the current and new observing systems, to identify and record any impact of the change;

(c) The details and history of local conditions, instruments, operating procedures, data processing algorithms and other factors pertinent to interpreting data (i.e. metadata) should be documented and treated with the same care as the data themselves;

(d) The quality and homogeneity of data should be regularly assessed as part of routine operations;

(e) Consideration of the need for environmental and climate-monitoring products and assessments, such as the Intergovernmental Panel on Climate Change (IPCC) assessments, should be integrated into national, regional and global observing priorities;

(f) The operation of historically uninterrupted stations and observing systems should be maintained;

(g) Data-poor regions, poorly observed parameters, regions sensitive to change, and key measurements with inadequate temporal resolution should be high-priority areas for additional observations;

(h) Long-term requirements, including appropriate sampling frequencies, should be specified to network designers, operators and instrument engineers at the outset of system design and implementation;

(i) A carefully planned conversion of research observing systems to long-term operations should be promoted;

(j) Data management systems that facilitate access to, and the use and interpretation of data and products should be included as essential elements of climate monitoring systems.

Furthermore, operators of satellite systems monitoring the climate need to:

– Take steps to make radiance calibration, calibration monitoring and satellite-to-satellite cross-calibration of the full operational constellation a part of the operational satellite system;

– Take steps to sample the Earth system in such a way that climate-relevant (diurnal, seasonal, and long-term interannual) changes can be determined.

2.2.2 Satellite systems for climate monitoring should adhere to the following specific principles:

(a) Constant sampling within the diurnal cycle (minimizing the effects of orbital decay and orbit drift) should be maintained;

(b) A period of overlap for new and old satellite systems should be ensured that is long enough to determine inter-satellite biases and maintain the homogeneity and consistency of time-series observations;

(c) Continuity of satellite measurements (i.e. elimination of gaps in the long-term record) through appropriate launch and orbital strategies should be ensured;

(d) Rigorous pre-launch instrument characterization and calibration, including radiance confirmation against an international radiance scale provided by a national metrology institute, should be ensured;

(e) Onboard calibration adequate for climate system observations should be ensured and associated instrument characteristics should be monitored;

(f) The operational provision of priority climate products should be sustained, and peer-reviewed new products should be introduced as appropriate;

(g) Data systems needed to facilitate user access to climate products, metadata and raw data, including key data for delayed-mode analysis, should be established and maintained;

(h) The use of functioning baseline instruments that meet the calibration and stability requirements stated above should be maintained for as long as possible, even when such instruments exist on decommissioned satellites;

(i) Complementary in situ baseline observations for satellite measurements should be maintained through appropriate activities and cooperation between space agencies and owners of in situ networks;

(j) Random errors and time-dependent biases in satellite observations and derived products should be identified.

APPENDIX 2.3. THE WMO ROLLING REVIEW OF REQUIREMENTS

1. GENERAL

The Rolling Review of Requirements (RRR) compiles information on Members' evolving requirements for observations in WMO application areas (a list of which is available at https://community.wmo.int/rolling-review-requirements-process) that directly use observations; the extent to which current and planned WIGOS component observing systems satisfy those requirements; guidance from experts in each application area on gaps and priorities, in order to tackle the deficiencies and opportunities in WMO observing systems; and plans for the future evolution of WIGOS component observing systems.

The application areas are:

(a) Global numerical weather prediction (GNWP);

(b) High-resolution numerical weather prediction (HRNWP);

(c) Nowcasting and very short-range forecasting (NVSRF);

(d) Seasonal and interannual forecasting (SIAF);

(e) Aeronautical meteorology;

(f) Forecasting atmospheric composition;

(g) Monitoring atmospheric composition;

(h) Atmospheric composition for urban applications;

(i) Ocean applications;

(j) Agricultural meteorology;

(k) Hydrology;

(l) Climate monitoring (as undertaken through the Global Climate Observing System (GCOS));

(m) Climate applications;

(n) Space weather;

(o) Climate science.

Note: A detailed and up-to-date description of the RRR process is available on the WMO website at https://community.wmo.int/rolling-review-requirements-process.

Observational requirements for WMO polar activities and the Global Framework for Climate Services (GFCS) are also being considered.

An expert is identified for each application area to be the Point of Contact. This expert has a very important role as the conduit to the RRR for input to and feedback from the entire stakeholder community for that application area.

The nominated Points of Contact should coordinate with their application area community (technical commission and WMO Programme or co-sponsored programme, as appropriate) as needed, in order to perform the following tasks:

(a) Investigate whether it is appropriate to represent the application area in several sub-applications;

(b) Submit the quantitative user observational requirements to the OSCAR/Requirements database (see https://community.wmo.int/oscar-wmo-observational-requirements-and-capabilities), review these requirements and keep them up to date, making changes as needed (the Points of Contact are provided with the required access rights);

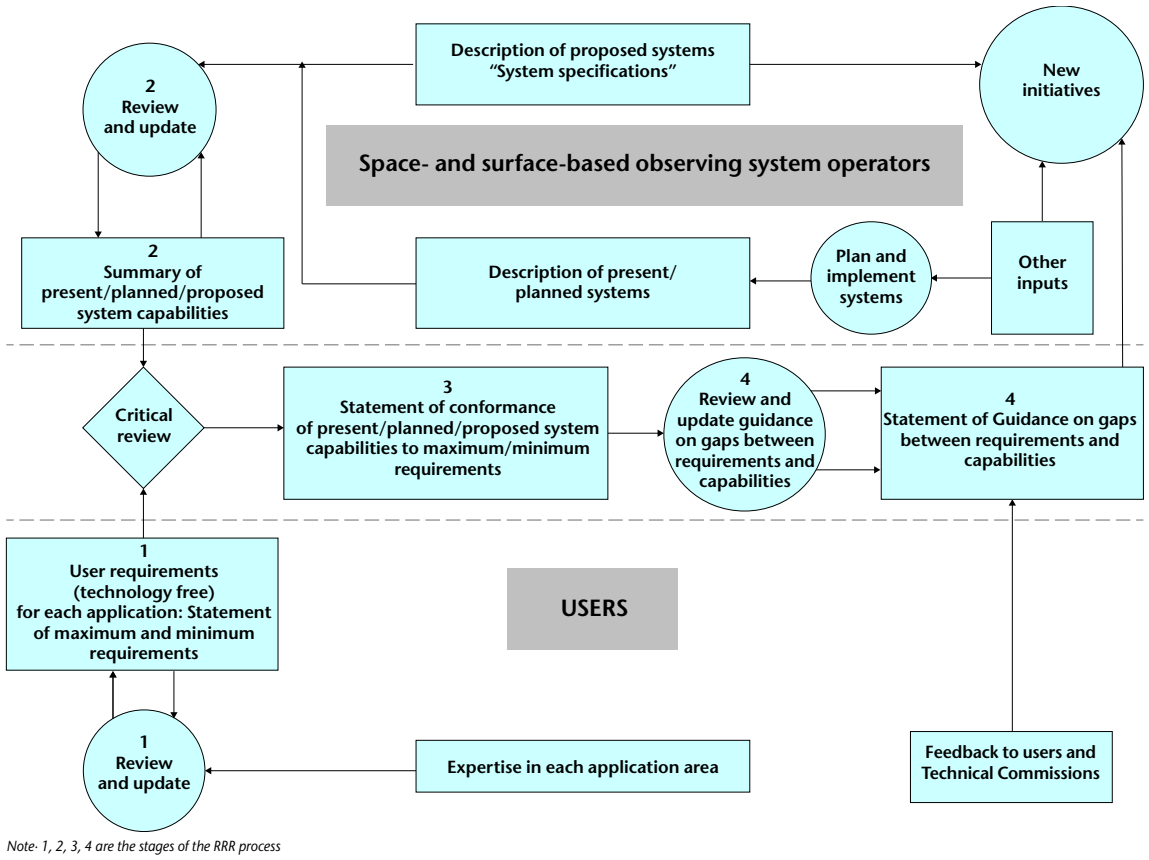
(c) Produce, review and revise the Statement of Guidance for their application area;

(d) Review how cross-cutting activities (for example, those related to the cryosphere and climate services) are taken into account in the user requirement database and in the Statement of Guidance for the application area.

Note: The user requirements for observations, compiled through the RRR process, are stored and made available by the WIGOS Information Resource (WIR, which includes the OSCAR/Requirements database) as described in detail in Attachment 2.3.

The RRR process consists of four stages, as illustrated in the figure below :

1. A review of technology-free (that is, not constrained by any particular type of observing technology) user requirements for observations, within each of the WMO application areas (see section 2.1);


Description of proposed systems "System specifications"
New initiatives
2 Review and update
Space- and surface-based observing system operators
2 Summary of present/planned/proposed system capabilities
Description of present/ planned systems
Plan and implement systems
Other inputs
Critical review
3 Statement of conformance of present/planned/proposed system capabilities to maximum/minimum requirements
4 Review and update guidance on gaps between requirements and capabilities
4 Statement of Guidance on gaps between requirements and capabilities
1 User requirements (technology free) for each application: Statement of maximum and minimum requirements
USERS
1 Review and update
Expertise in each application area
Feedback to users and Technical Commissions
Note: 1, 2, 3, 4 are the stages of the RRR process

Schematic representation of the steps included in the RRR process

2. A review of the observing capabilities of existing and planned observing systems, both surface- and space-based;

3. A critical review, that is a comparison of requirements with the observing system capabilities;

4. A Statement of Guidance providing a gap analysis with recommendations on how to address the gaps for each application area.

2. REVIEW OF USER REQUIREMENTS FOR OBSERVATIONS

Notes:
1. This stage of the RRR is described briefly in section 2.1.
2. Regional associations examine and provide Points of Contact with additional details for the compiled user requirements, taking into account the particular requirements of the Region and transboundary river basin authorities.

3. REVIEW OF CURRENT AND PLANNED OBSERVING SYSTEM CAPABILITIES

Members shall take steps for collecting, reviewing, recording and making available information on current and planned capabilities of observing systems.

Note: Information on observing system capabilities is in the form of metadata and is to be made available for global compilation according to the provisions of section 2.5.

4. THE CRITICAL REVIEW

Note: This WMO Programme activity proceeds with assistance from the Points of Contact of the application areas. It compares the quantitative user observational requirements of each application area with the observing system capabilities.

5. STATEMENTS OF GUIDANCE

Notes:
1. The Statement of Guidance interprets the output of the critical review as a gap analysis and identifies priorities for action: the most feasible, beneficial and affordable initiatives to deal with the identified gaps or shortcomings in WIGOS component observing systems for an application area. This draws on the subjective judgement and experience of the Points of Contact, the experts and other stakeholders they consult within their application area.
2. This stage of the RRR requires the Points of Contact to coordinate with their application area community and stakeholders, as needed, in order to produce, review and revise the Statement of Guidance for the application area.

APPENDIX 2.4. THE WIGOS METADATA STANDARD

1. GENERAL

This appendix refers to the WIGOS Metadata Standard, which consists of the set of observational metadata elements to be made available internationally, for the effective interpretation of observations from all WIGOS component observing systems by their users. In this way, metadata users can access important information about why, where and how an observation was made. Metadata also provide information on the processing of the raw data and data quality. Note that WIGOS metadata, which are required from specific components or subsystems, are detailed in sections 3–8 of this Manual.

The table below presents categories (or groups) of metadata, each containing one or more elements. Each element is classified (using the same terminology as the International Organization for Standardization (ISO)) as mandatory (M), conditional (C) or optional (O). In the table, the mandatory elements are shown in bold and the conditional elements in italics.

A more detailed definition of each metadata element, together with notes and examples, and an explanation of the conditions that apply to the conditional elements are specified in the *WIGOS Metadata Standard* (WMO-No. 1192).

2. MEMBERS' OBLIGATIONS

Mandatory metadata elements shall always be made available. The content of the corresponding fields shall never be empty: either the metadata value or, in specified cases, the reason for no-value shall be made available.

Conditional metadata elements shall be made available when the specified condition or conditions are met, in which case the content of the corresponding fields shall never be empty: either the metadata value or the reason for no-value shall be made available.

Optional metadata elements should be made available, as they provide useful information that can help to better understand an observation. These elements are likely to be important for a particular community, but less so for others.

3. ADOPTION THROUGH A PHASED APPROACH

Making WIGOS metadata available generates substantial benefits for Members, but developing the capacity to make these metadata available requires a substantial effort on the part of (meta) data providers. To help Members comply with reporting obligations, guidance material is provided in the *Guide to the WMO Integrated Global Observing System* (WMO-No. 1165).

Moreover, a phased approach was adopted during the implementation period as shown in the table. All Members are now expected to be compliant with the Standard in its entirety, however the three phases may still be a helpful reference for those Members, or operators within Member countries, who are developing their capacity to comply.

Elements emerging as being important for specific application areas or observing programmes will be added to the standard as it evolves.

List of elements specified in the WIGOS Metadata Standard, and the historical phases of implementation

Category	*Phase I*	*Phase II*	*Phase III*
	2016	*2017–2018*	*2019–2020*
1. Observed variable	**1-01 Observed variable – measurand (M)**	1-05 Representativeness (O)	
	1-02 Measurement unit (C)		
	1-03 Temporal extent (M)		
	1-04 Spatial extent (M)		
2. Purpose of observation	2-01 Application area(s) (O)		
	2-02 Programme/ network affiliation (M)		
3. Station/ platform	*3-01 Region of origin of data (C)*	**3-04 Station/platform type (M)**	3-10 Station/platform cluster (O)
	3-02 Territory of origin of data (C)	3-08 Data communication method (O)	
	3-03 Station/ platform name (M)		
	3-06 Station/ platform unique identifier (M)		
	3-07 Geospatial location (M)		
	3-09 Station operating status (M)		
4. Environment		4-04 Events at observing facility (O)	4-01 Surface cover (O)
		4-05 Site information (O)	*4-02 Surface cover classification scheme (C)*
			4-03 Topography or bathymetry (O)
			4-06 Surface roughness (O)
			4-07 Climate zone (O)

Category	*Phase I*	*Phase II*	*Phase III*
	2016	*2017–2018*	*2019–2020*
5. Instruments and methods of observation	**5-01 Source of observation (M)**	5-11 Maintenance party (O)	5-04 Instrument operating status (O)
	5-02 Measurement/ observing method (M)	*5-12 Geospatial location (C)*	*5-06 Configuration of instrumentation (C)*
	5-03 Instrument specifications (O)	*5-15 Exposure of instruments (C)*	5-07 Instrument control schedule (O)
	5-05 Vertical distance of sensor (C)		*5-08 Instrument control result (C)*
			5-09 Instrument model and serial number (O)
			5-10 Instrument routine maintenance (O)
			5-13 Maintenance activity (O)
			5-14 Status of observation (O)
6. Sampling	6-03 Sampling strategy (O)	6-05 Spatial sampling resolution (O)	6-01 Sampling procedures (O)
	6-07 Diurnal base time (C)		6-02 Sample treatment (O)
	6-08 Schedule of observation (M)		6-04 Sampling time period (O)
			6-06 Temporal sampling interval (O)
7. Data processing and reporting	**7-03 Temporal reporting period (M)**	*7-02* Processing/analysis centre (O)	*7-01* Data-processing methods and algorithms (O)
	7-04 Spatial reporting interval (C)	*7-06* Level of data (O)	*7-05* Software/processor type and version (O)
	7-11 Reference datum (C)	*7-09* Aggregation period (O)	*7-07* Data format (O)
		7-10 Reference time (O)	*7-08* Version of data format (O)
			7-12 Numerical resolution (O)
			7-13 Timeliness (of reporting) (O)
			7-14 Schedule of international exchange (M)
8. Data quality		8-01 Uncertainty of measurement (O)	
		8-02 Procedure used to estimate uncertainty (C)	
		8-03 Quality flag (O)	
		8-04 Quality flagging system (C)	
		8-05 Traceability (C)	

Category	*Phase I*	*Phase II*	*Phase III*
	2016	*2017–2018*	*2019–2020*
9. Ownership and data policy	**9-02 Data policy/use constraints (M)**	**9-01 Supervising organization (M)**	
10. Contact	**10-01 Contact (nominated focal point) (M)**		

APPENDIX 2.5. THE EIGHT PRINCIPLES OF QUALITY MANAGEMENT OF THE WMO QUALITY MANAGEMENT FRAMEWORK APPLIED TO WIGOS

1. User and client focus

Members should identify, document and understand the current and future needs of their users and clients for meteorological, climatological, hydrological, marine and related environmental observations.

Note: The means to achieve this includes participation in and application of the WMO Rolling Review of Requirements (RRR) (see section 2.2.4 and Appendix 2.3).

2. Leadership

Members should clearly define the goals and directions of their observing systems, and create an environment in which staff are encouraged to work towards those goals.

Note: The relevant WMO technical commissions provide technical guidance and leadership for the implementation of WIGOS. They provide information on WIGOS goals and directions, and stimulate the active involvement of technical experts from Member countries.

3. Involvement of experts

Experts from Member countries should be fully involved in the implementation of regulations pertaining to WIGOS quality management.

4. Process approach

Members should adopt a process-based approach to management of observing systems.

5. System approach to management

Members should identify, understand and manage WIGOS component observing systems as sets of processes that may be operational, scientific or administrative, with the overall objective of producing the required observation outputs.

6. Continual improvement

Members should ensure that continual improvement is an integral and permanent aspect of WIGOS component observing systems and is implemented through a range of processes and activities that include active participation in the WMO RRR; auditing of observing systems and sites; data quality monitoring and evaluation; and routine consultation with, and review of feedback from, WIGOS users and application areas, primarily through the WMO RRR.

Note: The outcome is the improvement of either the quality of observations or the efficiency of observing systems.

7. Factual approach to decision-making

Members should ensure that decisions, requirements and regulations associated with the design, development, implementation, operation, maintenance and evolution of WIGOS component observing systems are based on scientifically, factually and analytically derived information.

Note: The above-mentioned information is available to Members through tools such as the WMO RRR, the WIGOS Information Resource (WIR), the Observing Systems Capability Analysis and Review (OSCAR) tool, and through WMO endorsed planning documents such as the *Implementation Plan for the Evolution of Global Observing Systems* (EGOS-IP) (WIGOS Technical Report No. 2013-4). For further information see section 2.2.4, Appendix 2.3 and Attachment 2.3.

8. Mutually beneficial supplier relationships

Members should share with each other and with suppliers information and results of tests, trials and intercomparisons of instruments and systems, for the mutual benefit of both WIGOS and suppliers.

Note: Suppliers of instruments, systems and related products should be evaluated and selected on the basis of their ability to meet requirements and the past performance of their products and services.

ATTACHMENT 2.1. SPECIAL OBSERVATIONS IN EXTRAORDINARY CIRCUMSTANCES

1. GENERAL

In some WMO application areas, the requirements for observations change as circumstances change. The circumstances might be a brief period of extreme, unexpected or dangerous conditions, or a longer-lasting event such as volcanic activity, a tropical cyclone or an environmental emergency such as a nuclear accident. Seasonal changes also allow Members to achieve efficiencies by adapting to changing requirements. The requirements might be for additional times/frequency of observations, additional spatial location or resolution, or the inclusion of additional meteorological and non-meteorological variables. There might also be additional reporting requirements.

In some cases, special observations might be primarily designed for use in numerical weather prediction (NWP) by targeting sensitive areas during a specific weather event. Research carried out within The Observing System Research and Predictability Experiment (THORPEX) found that improving forecasts of tropical cyclone tracks can have positive impacts. In other cases, special observations might be primarily designed for use in other (non-NWP) modes of analysis and decision support.

2. SPECIAL OBSERVATIONS FOR TROPICAL CYCLONES

2.1 Aircraft weather reconnaissance flights

Members are encouraged to organize and share observations from aircraft weather reconnaissance flights for the analysis and prediction of developing or threatening tropical cyclones. Flight times and frequency should be selected to best supplement other upper-air and surveillance information.

These observations should include:

(a) Altitude and position of aircraft;

(b) Observations made at frequent intervals during a horizontal flight at low level;

(c) Observations made during flights at higher levels, as near as possible to standard isobaric surfaces;

(d) Vertical soundings, either by aircraft or by dropsonde.

The meteorological variables to be observed should include:

(a) Atmospheric pressure at which the aircraft is flying;

(b) Air temperature;

(c) Humidity;

(d) Wind (type of wind, wind direction and speed);

(e) Present and past weather;

(f) Turbulence;

(g) Flight conditions (cloud amount);

(h) Significant weather changes;

(i) Icing and contrails.

Note that "type of wind" refers to how the wind was determined and whether it was a mean or a spot wind.

2.2 Other observations

Surface marine observations and sub-surface ocean temperature and salinity measurements are also very useful for predicting the track and intensity of tropical cyclones.

References for other special observations during tropical cyclones will be provided in a future edition of this Manual.

3. SPECIAL OBSERVATIONS FOR ENVIRONMENTAL EMERGENCY RESPONSE ACTIVITIES

The meteorological and non-meteorological (for example, radiological, sulphur dioxide, particulates, etc.) observational data requirements listed below have to be met to enable the designated Regional Specialized Meteorological Centres (RSMCs) to provide Members with transport model products for an environmental emergency response. These observational data, particularly at or near the site of an accident, are also needed by Members so that they may take appropriate preventive and remedial action in case of release into the environment. In the case of a nuclear emergency, data should be made available promptly in accordance with the Convention on Early Notification of a Nuclear Accident (Article 5 (e)).

A. Meteorological data requirements

(1) The data needed to run transport models are the same as those specified for the production of weather forecasts based on numerical weather prediction models, and are given in the *Manual on the Global Data-processing and Forecasting System* (WMO-No. 485), 2.2.2.7, for nuclear environmental emergency response, and 2.2.2.8, for non-nuclear environmental emergency response.

(2) Additional data[1] from the accident site[2] and potentially affected area[3] are desirable, and should be available to the designated RSMC to improve the quality of information about the transport of pollutants. These should include:

(a) Wind, temperature and humidity, upper-air data;

(b) Precipitation (type and amount);

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[1] The words "additional data" are used with their usual meaning and not as in Resolution 40 (Cg-XII).

[2] Due to the wide variety of nuclear accidents, a precise definition of "accident site" is not possible. The accident site should be understood as the location where the accident occurs and the immediate surroundings within a range of a few kilometres.

[3] The area potentially affected depends on the state and evolution of the atmosphere over an extended area around the accident site, as well as on the nuclear event itself, and so it cannot be precisely defined in advance. The "potentially affected area" should, therefore, be understood as the area where (according to the information available, including the air transport pollution products, if already known) the nuclear pollutants are likely to be transported in the air or on the ground at a significant level over the natural (background) radioactivity. Advice on the extent of the potentially affected area may be obtained from the RSMC concerned as well as national authorities.

(c) Surface-air temperature;

(d) Atmospheric pressure;

(e) Wind direction and speed (surface and, in the case of a nuclear power plant, stack height);

(f) Humidity.

(3) The following systems should be in place to provide the data needed from the accident site in combination, as necessary and (when) possible:

(a) In an emergency, at the stations closest to and up to 500 km from the site of the accident, the frequency of observations should be increased to at least every hour for the duration of the emergency. Stocks of consumables should be stored for use in an emergency;

(b) In the case of a nuclear power plant, at least one radiosonde station should be located at a suitably safe distance, to enable continued operation in an emergency and to provide data representative of conditions at or near the accident site;

(c) In the case of a nuclear power plant, at least one surface station should be located at the site or, if this is not possible, at a nearby site. It should be convertible to an hourly automated mode for both operations and telecommunications in case of emergency;

(d) Additional information should be provided at or near the accident site by instrumented towers or masts (up to 100 m), where available, and by conventional or Doppler radars, SODARs, profilers, and boundary layer sondes, all with automatic transmission of data.

(4) The data needed from the potentially affected area should be provided as follows:

(a) All upper-air stations within the potentially affected area should make observations every six hours for the duration of the emergency;

(b) Where possible, one or more additional observing systems (including wind profilers and mobile radiosounding equipment) and ascent/descent data from aircraft should be provided;

(c) All surface (land and marine) stations/platforms within the potentially affected area, including those that do not normally exchange data internationally, should provide observational data to designated RSMCs. These include marine platforms and buoys because they can provide coverage of sea areas;

(d) A series of best estimates of precipitation should be made by combining information from direct measurements (automated or manual) of surface stations, composite radar information extending over the whole WMO Region and satellite-derived data.

B. Non-meteorological data requirements

(1) In case of emergency, non-meteorological data to be provided to designated RSMCs from the accident site should include:

(a) Start of release (date and time);

(b) Duration;

(c) Radionuclide species (nuclear emergency) and type of pollutant (non-nuclear emergency);

(d) Total release quantity or pollutant release rate;

(e) Effective height of release.

Point (a) is necessary for running transport models, while (b), (c), (d) and (e) are desirable additional data.

(2) In order to calibrate and validate the atmospheric transport model forecasts, data from potentially affected areas are needed. The most suitable data are:

Nuclear emergency:

(a) For each isotope, concentration (Bq/h) and, if available, time-integrated air concentration;

(b) Total deposition.

Non-nuclear emergency:

This will depend on the pollutant and the nature of the release but, typically, measurements of the concentration would be appropriate.

(3) The required data from the accident site and potentially affected area may be obtained by the following means:

(a) Fixed monitoring stations;

(b) Mobile surface units;

(c) Sounding; or

(d) Instrumented aircraft.

The frequency of non-meteorological observations should be increased to at least once per hour.

C. Exchange of meteorological and non-meteorological data

(1) Non-meteorological data and, to some extent, additional meteorological data are likely to be provided by non-meteorological national authorities. The National Meteorological or Hydrometeorological Services (NMSs) should encourage the provision of these data by non-meteorological agencies/operators to National Meteorological Centres (NMCs) for onward transmission to their associated RSMCs.

(2) In case of environmental emergencies, all relevant observational (meteorological and non-meteorological) data should be transmitted to both RSMCs and NMSs through the WMO Information System (WIS) as quickly as possible. In the case of a nuclear emergency, radiological data available in the early phase of a nuclear accident that can help characterize the accident (containment radiation reading, on-site radiation levels, etc.) should be provided by national authorities to the International Atomic Energy Agency (IAEA) as soon as is practicable via the most reliable means of communication. The IAEA will verify and assess the information, and then provide these data to the appropriate RSMCs.

(3) End-to-end testing of procedures for data acquisition, quality control and communication, and product dissemination should be carried out periodically to ensure system performance.

4. SPECIAL OBSERVATIONS IN THE EVENT OF VOLCANIC ACTIVITY

Requirements in the event of volcanic activity potentially hazardous to aviation should be related to the observational data needed by Members for taking appropriate action; these data are specified below.

The International Airways Volcano Watch (IAVW) is coordinated and developed by the International Civil Aviation Organization (ICAO) Secretariat with the assistance of ICAO Meteorology Panel. The *Handbook on the International Airways Volcano Watch (IAVW)* (ICAO Doc 9766-AN/968) describes the operational procedures and the contact list for the implementation of the IAVW in the event of pre-eruption volcanic activity,[4] volcanic eruptions and volcanic ash clouds.

A. Meteorological data requirements

The data needed to run transport models are the same as specified for the production of weather forecasts based on numerical weather prediction models, and are given in the *Manual on the Global Data-processing and Forecasting System* (WMO-No. 485), 2.2.2.8.

(1) Additional data[5] are desirable from the area in the vicinity of the volcano and should be made available to the designated Meteorological Watch Offices and Volcanic Ash Advisory Centre (VAAC)[6] to improve the quality of information about the transport of volcanic ash. These data are the same as specified for the special observational requirements for environmental emergency response activities, and are given in this Attachment, section 3.

(2) Imagery data from geostationary and polar-orbiting satellites are required by the designated VAAC to ascertain whether a volcanic ash cloud is identifiable and to determine its extent (vertical and horizontal) (see the *Handbook on the International Airways Volcano Watch (IAVW)* (ICAO Doc 9766-AN/968), Part 4. These data are also required to validate the transport model trajectory forecast and to determine when the volcanic ash has dissipated. The imagery data should:

   (a) Be multi-spectral, covering visible and infrared wavelengths;

   (b) Have adequate spatial resolution to detect small volcanic ash clouds (5 km or less);

   (c) Have global coverage to provide data for all the VAACs;

   (d) Have a frequent repeat cycle (30 minutes or less for the detection of volcanic ash and at least every six hours for the tracking of volcanic ash for transport model validation) (see *Handbook on the International Airways Volcano Watch (IAVW) (ICAO Doc 9766-AN/968)*, sections 4.5.1 (d) and 4.6.1 (d) and (e);

   (e) Be processed and delivered to the VAAC with minimal delay.

(3) Additional satellite data that can assist in the detection of pre-eruption volcanic activity, a volcanic eruption, or a volcanic ash cloud should be made available to the designated VAAC. These may include satellite data that can be used to detect volcanic hot-spots or sulphur dioxide emissions.

(4) Data obtained from surface-based radar within range of the volcano should be made available to the designated VAAC. These data can be used to detect the presence of a volcanic ash cloud and measure its height.

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[4] Pre-eruption volcanic activity in this context means unusual and/or increasing volcanic activity, which could presage an eruption.

[5] The words "additional data" are used with their usual meaning and not as in Resolution 40 (Cg-XII).

[6] Volcanic Ash Advisory Centres are designated by ICAO in coordination with WMO to issue advisories on the presence of volcanic ash and its forecasted trajectory.

B. Non-meteorological data requirements

(1) The occurrence of pre-eruption volcanic activity, volcanic eruptions and volcanic ash clouds, because of the potential hazard to aviation, should be reported without delay to the designated Area Control Centres, Meteorological Watch Offices and VAAC, as described in *the Handbook on the International Airways Volcano Watch (IAVW)* (ICAO Doc 9766-AN/968). The report, in plain language, should be made in the form of a volcanic activity report comprising the following information, if available, in the order indicated:

(a) Message type: VOLCANIC ACTIVITY REPORT;

(b) Station identifier, location indicator or name of station;

(c) Date/time of message;

(d) Location of volcano and name, if known;

(e) Concise description of event including, as appropriate, level of intensity of volcanic activity, occurrence of an eruption and its date and time, and existence of a volcanic ash cloud in the area (with the direction of ash cloud movement and height, as best estimated).

(2) Available geological data that indicates the occurrence of pre-eruptive volcanic activity or a volcanic eruption should be passed immediately to the designated Area Control Centres, Meteorological Watch Offices and VAAC (see the *Handbook on the International Airways Volcano Watch (IAVW)* (ICAO Doc 9766-AN/968), section 4.1.1 (d)). These data include:

(a) Vulcanological observations;

(b) Seismological activity reports.

(3) Pilot reports of pre-eruption volcanic activity, volcanic eruptions and volcanic ash clouds should be sent without delay to the designated Area Control Centres, Meteorological Watch Offices and VAAC (See the *Handbook on the International Airways Volcano Watch (IAVW)* (ICAO Doc 9766-AN/968), section 4.1.1 (d)).

C. Exchange of meteorological and non-meteorological data

The exchange of all the above data is described in the *Handbook on the International Airways Volcano Watch (IAVW)* (ICAO Doc 9766-AN/968).

ATTACHMENT 2.2. WIGOS STATION IDENTIFIERS

1. STRUCTURE OF WIGOS STATION IDENTIFIERS

Figure 1 shows the structure of the WIGOS station identifier. The description of each component is given in the table below.

WIGOS station identifier series	Issuer of identifier	Issue number	Local identifier

Figure 1. Structure of the WIGOS station identifier

Component parts of the WIGOS station identifier

Component	*Description*	*Initial range – series 0 (stations)*
WIGOS station identifier series	This is used to distinguish between different systems for allocating identifiers. It allows future expansion of the system so that entities do not have to be issued with new identifiers if the structure of the WIGOS station identifiers proves unable to meet future requirements. Different values of the WIGOS station identifier series may correspond to different structures of the identifier. Initial permitted range: 0-14.	0
Issuer of identifier	A number that is used to distinguish between identifiers issued by different organizations. It is allocated by WMO to ensure that only one organization can create a given WIGOS station identifier.	0-65534
Issue number	A number that an organization responsible for issuing an identifier may use to ensure global uniqueness of its identifiers. For example, allocating one issue number for hydrological stations and another for voluntary climate observing stations would enable the managers of the two networks to issue local identifiers independently without needing to check with each other that they were not duplicating identifiers.	0-65534
Local identifier	This is the individual identifier issued for each entity. An organization issuing identifiers must ensure that the combination of issue number and local identifier is unique; in that way global uniqueness is guaranteed.	16 alphanumeric characters

Notes:

1. The structure of WIGOS station identifiers has been designed to be general enough to identify other entities, such as individual instruments; however, this has not yet been implemented.
2. Although the table proposes initial ranges of permitted values of the components that make up a WIGOS station identifier, future changes in requirements may result in these ranges being increased. Information technology systems must, therefore, be designed to process identifiers whose components are of different lengths. BUFR encodings will need to be prepared for WIGOS station identifiers to allow efficient representation and these may use code lists to represent components of the identifier that are shared by many entities. Currently, WIGOS station identifier = 0.
3. Alphanumeric characters are the set of 62 characters including all the uppercase letters from A to Z, all the lowercase letters a-z and all the digits from 0 to 9. Symbols and special characters are not allowed in the set of alphanumeric characters to be used for the local identifier.

2. NOTATION FOR THE WIGOS STATION IDENTIFIER

The convention for writing WIGOS station identifiers (in the context of WIGOS) is:

<WIGOS station identifier series>-<issuer of identifier>-<issue number>-<local identifier>

Here is an example of a WIGOS station identifier:

WIGOS station identifier series	Issuer of identifier	Issue number	Local identifier
0	513	215	5678

which would be written as 0-513-215-5678.

3. REPRESENTING THE WIGOS STATION IDENTIFIER IN CONTEXTS OUTSIDE WIGOS

The following convention (Figure 2) should be used to represent the WIGOS station identifier outside WIGOS or to show the relationship between the WIGOS station identifier and an identifier that has been defined in a different context:

int.wmo.wigos	WIGOS station identifier	WIGOS supplementary identifier

Figure 2. Structure of an extended WIGOS station identifier

Both the int.wmo.wigos and the WIGOS supplementary identifier elements are optional.

int.wmo.wigos

The first component of the extended WIGOS station identifier (int.wmo.wigos) allows it to be recognized as a WIGOS station identifier when used in contexts where it may be unclear what type of identifier is being used. This is optional and need not be represented in BUFR, because the entries for the WIGOS station identifier provide this information;

WIGOS station identifier

The second component (WIGOS station identifier) is defined above. Within a WIGOS context it is the only component of the WIGOS station identifier that is always required;

WIGOS supplementary identifier

The final component (WIGOS supplementary identifier) is optional and is used to associate identifiers issued using other systems with the WIGOS unique identifier. A single WIGOS station identifier may be associated with many WIGOS supplementary identifiers (such as an observing site that is used for both synoptic and aviation reporting), and a WIGOS supplementary identifier may be associated with many WIGOS unique identifiers (such as a World Weather Watch drifting buoy identifier that has been issued to many drifting buoys). In BUFR, this would be indicated by a specific table entry (such as IIiii for World Weather Watch station identifier).

Note: If the above example of a WIGOS station identifier (0-513-215-5678) was also associated with an identifier (MYLOCATION) issued by another authority, a valid extended WIGOS station identifier would be int.wmo.wigos-0-513-215-5678-MYLOCATION.

4. ENTITIES RECOGNIZED AS ISSUERS OF IDENTIFIERS

The following entities are recognized as "Issuers of WIGOS Station Identifiers" (or WSI Issuers) with delegated authority to issue WSIs for observing stations that contribute to a WMO or co-sponsored programme on behalf of Members. Where there is a Member with a geographic area of responsibility, the Member should be first requested to issue a WSI for the station. If the Member does not provide a WSI, or does not reply, the WSI Issuer for the programme/ organization concerned will issue the WSI.

(1) The Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO);

(2) The relevant authority for the observing component of the Global Atmosphere Watch (GAW);

(3) The relevant authority for the observing component of the Global Cryosphere Watch (GCW);

(4) The relevant authority for the Global Climate Observing System (GCOS) Reference Upper-Air Network (GRUAN);

(5) The WMO Radar Database (WRD), hosted by the Turkish State Meteorological Service (TSMS);

(6) The Copernicus Climate Change Service (C3S) operated by the European Centre for Medium-Range Weather Forecasts (ECMWF), on behalf of the European Union, under contract "311a Lot 2: Global Land and Marine Observations Database".

These WSI issuers will be given a distinct Issuer of Identifier code, for the second block in the WSIs structure, that clearly distinguishes them from those WSIs nationally issued by the Permanent Representatives of Members with WMO.

The relevant procedures for each entity mentioned above are described in the *Guide to the WMO Integrated Global Observing System* (WMO-No. 1165).

ATTACHMENT 2.3. THE WIGOS INFORMATION RESOURCE

1. PURPOSE

The WIGOS Information Resource (WIR) is a tool designed to provide WIGOS stakeholders (observing network decision-makers, managers, supervisors, implementation coordination groups and observational data users) with all relevant information on the operational status and evolution of WIGOS and its observing components, and their capabilities to meet the user observational requirements of the WMO application areas; the operational requirements of WIGOS, including standard and recommended practices and procedures; and on best practices and procedures used in the WIGOS framework. The WIR serves a number of purposes and brings the following benefits to WMO Members:

(a) General information on WIGOS, its benefits to Members and the impact on Members of addressing WIGOS requirements;

(b) An overall description of the WIGOS component observing systems that are currently in place (list of observing networks, stations, their characteristics (metadata) including information on the observational products they deliver);

(c) Monitoring of the evolution of the observing systems to ascertain their progress in terms of the initial plans;

(d) An outline of existing national and regional plans for evolution of WIGOS component observing systems;

(e) Help, for Members and those in charge of designing and implementing observing networks, in understanding the requirements for the relevant observing systems, including standard and recommended practices and procedures and user observational requirements, in order for them to make appropriate decisions;

(f) Assistance for Members in identifying observational gaps through critical review and in conducting network design studies, in order for them to address those gaps;

(g) Help for Members in grasping the full potential of the current observing systems, including those operated by partner organizations, with regard to the WMO application areas, in order to enhance: (a) the scope and availability of observations made by specific observing stations; (b) collaboration; (c) data sharing; and (d) data exchange;

(h) Immediate access for data users to the list of WIGOS component observing systems and a basic set of observational metadata for each (specified by WMO Technical Regulations), with links to the appropriate national databases, where these exist, which contain more detailed information;

(i) Guidance for developing countries on observing network implementation, providing them with tools they can readily use to document their own observing systems (for example, by using the Observing Systems Capability Analysis and Review (OSCAR) tool of the WIR, they would not need to develop a national database);

(j) A mechanism for matching specific needs (capacity building, closing gaps, etc.) with resources (via knowledge sharing, donor contributions, etc.).

Notes:

1. The term observing station refers to any type of observing site, station or platform relevant to WIGOS, whether they are surface-based or space-based, on land, at sea, in a lake, river or in the air, fixed or mobile, and making in situ or remote observations.

2. Gaps are expressed in terms of required space and time resolution, observing cycle, timeliness and uncertainty for the WMO application areas.

2. THE OBSERVING SYSTEMS CAPABILITY ANALYSIS AND REVIEW TOOL

The Observing Systems Capability Analysis and Review tool of the WIR is a key source of information for WIGOS metadata. The surface- and space-based components of OSCAR are intended to record observing platform/station metadata, according to the WIGOS Metadata Standard described in the present Manual and in the *WIGOS Metadata Standard* (WMO-No. 1192), and to retain a record of the current and historical WIGOS metadata.

The space-based component of OSCAR has a long history which precedes the development of the WIGOS Metadata Standard; therefore, while it strives to achieve consistency, there will be some differences between its structure and the Standard.

The third component of OSCAR is the database of user requirements for observations. It contains the technology-free requirements of each WMO application area. Requirements for geophysical variables are expressed in terms of six criteria: uncertainty, horizontal resolution, vertical resolution, observing cycle, timeliness and stability (where appropriate).

The requirements are regularly reviewed by groups of experts nominated by these organizations and programmes. For WMO, this process is conducted by the Inter-Programme Expert Team on Observing System Design and Evolution (IPET-OSDE) and its designated focal points for each of the application areas.

3. MANAGEMENT OF THE OBSERVING SYSTEMS CAPABILITY ANALYSIS AND REVIEW TOOL

The management of OSCAR (for example, its functional specifications and their evolution) and its components is overseen by the WMO Secretariat in liaison with relevant expert groups and bodies, and in accordance with the WIGOS standards that have been agreed upon and recommended practices and procedures.

4. CONTENT MANAGEMENT OF THE OBSERVING SYSTEMS CAPABILITY ANALYSIS AND REVIEW TOOL

The WIGOS metadata are under the authority of the Permanent Representatives with WMO.

The operator of OSCAR will collect feedback from Members on noted discrepancies, possible errors and required changes, so that the information content of OSCAR reflects the reality of the surface- and space-based capabilities of the observing platforms/stations they operate, including instrument and platform/station metadata.

The WMO Secretariat is responsible for coordinating management of the information content of OSCAR, with assistance from designated experts and focal points.

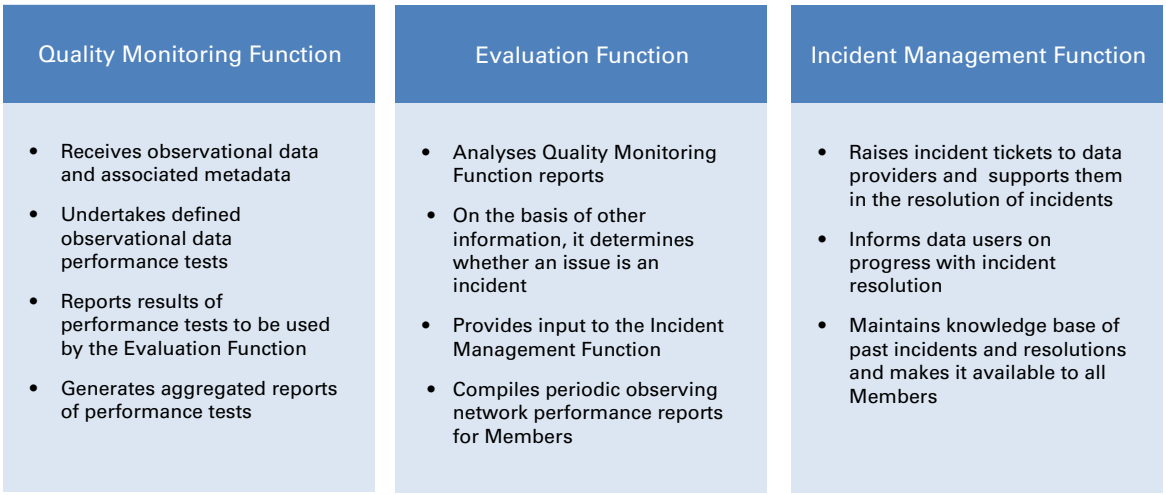
Current information can be found at https://community.wmo.int/oscar and https://community.wmo.int/oscar-wmo-observational-requirements-and-capabilities.

ATTACHMENT 2.4. THE WIGOS DATA QUALITY MONITORING SYSTEM

The WIGOS Data Quality Monitoring System (WDQMS) consists of:

- The WIGOS Quality Monitoring Function;
- The WIGOS Evaluation Function;
- The WIGOS Incident Management Function.

These three functions define the scope of WDQMS.


Quality Monitoring Function
Receives observational data and associated metadata
Undertakes defined observational data performance tests
Reports results of performance tests to be used by the Evaluation Function
Generates aggregated reports of performance tests
Evaluation Function
Analyses Quality Monitoring Function reports
On the basis of other information, it determines whether an issue is an incident
Provides input to the Incident Management Function
Compiles periodic observing network performance reports for Members
Incident Management Function
Raises incident tickets to data providers and supports them in the resolution of incidents
Informs data users on progress with incident resolution
Maintains knowledge base of past incidents and resolutions and makes it available to all Members

The high-level WDQMS functional diagram

Entities or bodies undertaking WDQMS functions

The WDQMS functions can be undertaken by one, two or three separate bodies: the number of bodies may vary depending on the WIGOS observing component being considered. These bodies will be known as the WIGOS Quality Monitoring, the WIGOS Evaluation and the WIGOS Incident Management Centres, respectively.

In the case of the land stations of GOS, the WIGOS Evaluation Function and Incident Management Function will be undertaken by Regional WIGOS Centres (RWC)[1] to cover a whole WMO Region or a subregion.

Where a quality monitoring, evaluation or incident management function is best undertaken on a global basis, for example, for ozone observations, a thematic or global centre or centres[2] should be established.

The exact nature of the configuration of the three functions and the selection of global or regional centres will be most strongly informed by the common operating practice implemented within that sub-component of the WIGOS observing components and co-sponsored observing systems.

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[1] Further guidance on WDQMS is provided in the *Guide to the WMO Integrated Global Observing System* (WMO-No. 1165), Chapter 8.

[2] Thematic or global WIGOS centre (T/GWC): a WMO centre (physical, virtual or distributed) in charge of one or more of the WDQMS functions with a global scope for a specific WIGOS observing system/component.

The WIGOS Quality Monitoring Function

The WIGOS Quality Monitoring Function will:

- Compare the observational data received at the WIGOS Quality Monitoring Centre[3] against agreed user requirements for observational data. These agreed requirements will include availability, timeliness of delivery and observational data quality, including completeness;
- Require access to the official sources of observational metadata, for example, OSCAR/Surface for the surface-based observations, for the internationally exchanged observations that will be assessed;
- Generate reports of results of comparisons of the received data with the expected availability, timeliness and observational quality criteria. These reports will be in pre-defined formats following agreed generation and dissemination criteria;
- Publish the reports generated, in the context of agreed data access rules;
- Generate statements of fact based on data and evidence rather than subjective judgements on observing system performance.

The WIGOS Evaluation Function

The WIGOS Evaluation Function:

- Will take the outputs of the WIGOS Quality Monitoring Function and any other relevant information to check them in context and determine if there is an issue with the observational data received at the WIGOS Quality Monitoring Centre or some other component of WIGOS, such as the metadata records held in OSCAR/Surface;
- May also act on information supplied from other sources, such as the WMO Information System (WIS) or individual Members, and may use that information and other sources to determine if an issue exists;
- Will use agreed business rules to determine if any issues identified require an incident to be raised with the appropriate operating authority (data providers) for the observational data;
- Will pass the request for an incident to be raised, along with all the supporting information, to the Incident Management Function for implementation;
- Will compile routine reports on the quality of the observational data received by the WIGOS Quality Monitoring Function for the operating authorities and data users. The frequency of this reporting will vary depending on the specific WIGOS component observing system under consideration.

The WIGOS Incident Management Function

The WIGOS Incident Management Function will:

- Flag an incident in accordance with a request from the WIGOS Evaluation Function, forward the Incident Ticket thus generated, with all appropriate additional information, to the relevant observing system operating authority, and track progress in the incident investigation and resolution;

[3] WIGOS quality monitoring centre (WQMC): a WMO centre (physical, virtual or distributed) in charge of the WIGOS Quality Monitoring Function with a global or regional scope for one or more WIGOS observing systems/components.

– Support, as appropriate, the observing system operating authority during investigation and resolution of the incident;

– Maintain a record of all incidents raised and the activities undertaken to resolve the incidents, making this information available to Members as a knowledge base for future incident resolution;

– Make available to the observational data users information about progress in the investigation and resolution of incidents.

Operating practices for WDQMS and its functions

To ensure consistency of quality monitoring, evaluation and incident management action, compliance with the operating practices and procedures associated with the WDQMS will need to be carefully monitored.

Operating practices and procedures to be followed by the quality monitoring centres will be developed by the working entity in charge of WDQMS.

Operating practices and procedures to be followed by a Regional WIGOS Centre (RWC) will be developed by the respective regional association or respective RWC oversight bodies.

Operating practices and procedures to be followed by thematic or global centres will be developed by their oversight or governance bodies.

Technical Guidelines for Regional WIGOS Centres on the WIGOS Data Quality Monitoring System (WMO-No. 1224) provides detailed technical guidance for RWCs to run the operational activities related to the WDQMS, specifically for the surface stations of the Global Observing System (GOS) located on land (on the territories of Members of WMO regional associations).

3. ATTRIBUTES SPECIFIC TO THE SURFACE-BASED SUBSYSTEM OF WIGOS

3.1 REQUIREMENTS

Note: The user observational requirements of WMO application areas are expressed in a technology-free manner, hence they apply to all of WIGOS, not to any specific subsystem. The provisions of section 2.1 apply across all WIGOS subsystems.

3.2 DESIGN, PLANNING AND EVOLUTION

3.2.1 Composition of the surface-based subsystem of WIGOS

3.2.1.1 The WIGOS surface-based subsystem shall be composed of surface stations within the component networks (GOS, GAW, WHOS, GCW).

Notes:

1. A prominent element of the WIGOS surface-based subsystem is the Regional Basic Observing Network (RBON) as described in 3.2.3. Other elements generally exist within one of the component networks as described in sections 5–8.
2. Information regarding the current capabilities of the surface-based subsystem is to be available through OSCAR at https://community.wmo.int/oscar and https://community.wmo.int/oscar-wmo-observational-requirements-and-capabilities. This information includes the list of surface stations/platforms that compose the WIGOS surface-based subsystem.

3.2.2 Global Basic Observing Network

3.2.2.1 The Global Basic Observing Network (GBON) shall be a subset of the surface-based subsystem of WIGOS, used in combination with the space-based subsystem and other surface-based observing systems of WIGOS, to contribute to meeting the requirements of Global NWP, including reanalysis in support of climate monitoring.

3.2.2.2 Members shall establish and manage GBON.

Notes:

1. Global NWP provides an essential backbone for all products and services provided by all WMO Members. The geographically relevant component of GBON provides an essential base component within each Regional Basic Observing Network (see 3.2.3 below).
2. GBON is based on a global design and the implementation is monitored globally.
3. GBON is designed to respond primarily to those Global NWP requirements that are currently not met, or not fully met, by space-based systems.
4. The specification for GBON is laid out in provisions 3.2.2.7–3.2.2.20. These are derived from the observational requirements for Global NWP that are recorded in the OSCAR/Requirements database together with an analysis of the operational technologies for collecting such observations and availability of observations from other sources. The technical assessment is conducted for the World Meteorological Congress by the Commission for Observation, Infrastructure and Information Systems (INFCOM).
5. The list of GBON stations/platforms is drawn from the list of all available stations/platforms in WIGOS as registered in OSCAR/Surface by the Members. The identification of the subset to be proposed by Members for GBON designation is based on the specification of GBON listed below. The list of GBON stations/platforms is elaborated in collaboration between the Members and INFCOM.

3.2.2.3 **Members shall maintain the continuous operation of those stations/platforms that are designated as contributors to GBON.**

Note: The designation process is defined in 3.2.2.22–3.2.2.23 below and further detailed in the *Guide to the WMO Integrated Global Observing System* (WMO-No. 1165).

3.2.2.4 **Members shall strive to design, install, manage, and operate stations within their networks in an environmentally sustainable fashion.**

3.2.2.5 **Members shall make available internationally through WIS all GBON observations in real time or near-real time according to the overall WMO data policy.**

3.2.2.6 **If a Member finds that the horizontal and/or temporal resolution required according to one or more of provisions 3.2.2.7-3.2.2.18 is not practically achievable for the observing network within parts of their territory, the Member shall inform the Secretary-General of the reasons as per Article 9(b) of the WMO Convention, and the *Technical Regulations* (WMO-No. 49), Volume I, General Provisions, paragraph 6.**

3.2.2.7 **Members shall maintain the continuous operation of a set of surface land stations/platforms that observe, at a minimum, atmospheric pressure, air temperature, humidity, horizontal wind, precipitation and snow depth, where applicable, located such that GBON has a horizontal resolution of 200 km or higher for all of these variables, with an hourly frequency.**

Notes:
1. The precipitation observation means an hourly accumulation.
2. The snow depth measurement is reported in accordance with the provisions of 5.1.6 and 5.1.7 of this Manual.
3. The *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume II provides details on measurement of snow.
4. A horizontal resolution of 200 km or higher means that stations/platforms are spaced not more than 200 km apart on average.
5. Many manual stations/platforms observe less frequently than hourly; these nevertheless provide a valuable contribution to GBON.
6. The provisions do not imply that every station/platform must measure all the variables listed, but that the network as a whole delivers observations at the required horizontal resolution for all the variables.

3.2.2.8 Members should operate surface land observing networks/platforms at horizontal resolutions of 100 km or higher.

3.2.2.9 **Where Members operate networks as described in 3.2.2.7 and 3.2.2.8, Members shall make the observations of these networks available internationally according to 3.2.2.5.**

3.2.2.10 **Where applicable, Members shall maintain the continuous operation of a set of surface marine meteorological observing stations/platforms within their Exclusive Economic Zone, or the corresponding marine areas of their jurisdictions, that observe, at a minimum, atmospheric pressure and sea surface temperature, located such that where opportunity exists, GBON has a horizontal resolution of 500 km or higher, over the marine areas of their jurisdictions, for these variables, with an hourly frequency.**

Note: For small island developing States where the surface area of the Exclusive Economic Zone is significantly larger than the land surface area, this provision applies to the entirety of the area of observing responsibility.

3.2.2.11 Where applicable, Members should facilitate other Members sharing surface marine meteorological observations within their Exclusive Economic Zone, or the corresponding marine areas of their jurisdictions, subject to the data being made available internationally according to 3.2.2.5.

3.2.2.12 **Members shall maintain the continuous operation of a set of upper-air stations/platforms over land that observe, at a minimum, temperature, humidity and horizontal wind, with a vertical resolution of 100 m or higher, twice a day or better, up to a level of 30 hPa or higher, located such that GBON has a horizontal resolution of 500 km or higher for these observations.**

Notes:
1. Radiosonde systems currently provide the primary means for collecting such observations.
2. A vertical resolution of 100 m or higher means that observations are spaced and reported not more than 100 m apart in the vertical on average.
3. Upper-air observations obtained over remote/isolated islands have a particularly high impact on Global NWP skill, and continued operation of these stations/platforms is of high priority for GBON.

3.2.2.13 Members should operate networks of upper-air stations/platforms providing horizontal resolutions of 200 km or higher.

3.2.2.14 Members should operate a subset of the selected GBON upper-air observing stations/platforms that observe temperature, humidity and horizontal wind up to 10 hPa or higher, at least once per day, located such that, where geographical constraints allow, GBON has a horizontal resolution of 1 000 km or higher, for these observations.

3.2.2.15 **Members shall operate a set of upper-air stations/platforms that observe temperature, humidity and horizontal wind, with a vertical resolution of 100 m or higher, twice a day or better, up to 30 hPa or higher, located such that, where opportunity exists, GBON has a horizontal resolution of 1 000 km or higher over the marine areas of their jurisdictions, for all these observations.**

Note: For small island developing States where the surface area of the Exclusive Economic Zone is significantly larger than the land surface area, this provision applies to the entirety of the area of observing responsibility.

3.2.2.16 **Where networks described in 3.2.2.10 and 3.2.2.12–15 are operated, 3.2.2.5 shall apply.**

3.2.2.17 Members should make available aircraft meteorological observations of temperature, humidity (where available) and horizontal wind from aircraft ascents and descents, with 300 m or higher vertical resolution with an hourly frequency or higher.

Note: For aircraft meteorological observations received from any source, conditions on the use, re-use and sharing of such data may be applied by licensing agreements or other appropriate arrangements.

3.2.2.18 Members should make available aircraft meteorological observations of temperature, humidity (where available) and horizontal wind, with a horizontal resolution of 100 km or higher, while at level flight.

Note: Note under 3.2.2.17 applies.

3.2.2.19 Members should make available hourly remote-sensing profiler observations of temperature (where available), humidity (where available) and horizontal wind with a vertical resolution of 100 m or higher.

3.2.2.20 Members operating observing networks/platforms at higher density than specified above under the provisions 3.2.2.7–3.2.2.19 should make available what is observed at least hourly.

Note: 15 km is the current goal of Global NWP requirements.

3.2.2.21 **Members shall make available the metadata of their GBON observing stations/platforms in accordance with the provisions of section 2.5.**

3.2.2.22 Each Member shall designate at a minimum the required number of surface stations and the required number of upper-air stations as per 3.2.2.7-3.2.2.10 and 3.2.2.12-3.2.2.15 as their contribution to GBON.

Notes:
1. INFCOM will undertake an initial GBON implementation analysis that will provide, for each Member, the number of surface stations and the number of upper-air stations that are required for the Member to meet their obligations under 3.2.2.7–3.2.2.10 and 3.2.2.12–3.2.2.15.
2. For each Member, INFCOM will review their designated contribution as per 3.2.2.21 and assess whether it meets the requirements specified in 3.2.2.7–3.2.2.10 and 3.2.2.12–3.2.2.15, and will inform the Member in writing of its findings.
3. See Note 3 below 3.2.2.12.

3.2.2.23 Members shall register the stations in OSCAR/Surface and identify that these stations belong to GBON.

3.2.2.24 Members shall routinely monitor GBON performance across the network to identify non-conformance with the designed performance.

Note: Guidance on data quality monitoring, evaluation and incident management is detailed in the *Guide to the WMO Integrated Global Observing System* (WMO-No. 1165), Chapter 8.

3.2.2.25 Members shall acknowledge, document and rectify any identified non-conformance at one of their stations/platforms within time frames agreed by the WMO Executive Council or the World Meteorological Congress.

Note: Details on relevant time frames and processes are provided in the *Guide to the WMO Integrated Global Observing System* (WMO-No. 1165).

3.2.2.26 Members shall formally notify the Secretary-General, at least three months in advance, of their plan to discontinue the operation of their stations/platforms.

3.2.3 Regional Basic Observing Network

3.2.3.1 Members shall establish and manage the RBON in their Region and the Antarctic.

Notes:
1. The former Regional Basic Synoptic Network (RBSN) and Regional Basic Climatological Network (RBCN) in each Region were the predecessors of RBON. The previous focus on the requirements of synoptic meteorology and climate monitoring is now expanded to include all WMO application areas. Similarly, the network of synoptic and climatological stations is now expanded with the inclusion of other stations/platforms, for example, aircraft stations.
2. The former Antarctic Observing Network (AntON) was the predecessor of RBON in the Antarctic; this will be managed by Members that contribute observations in the Antarctic to WIGOS.

3.2.3.2 Members shall design RBONs using existing observing systems within WIGOS in the Regions and the Antarctic.

3.2.3.3 Members shall nominate an observing station/platform for inclusion in RBON only if it meets one or more requirements of one or more WMO application areas.

Notes:
1. WMO application areas have a range of requirements, as explained further in Attachment 3.1. The greater the number of requirements met by a station/platform, the greater its value in general for inclusion in RBON.
2. Attention must be given to a multi-station or regional level assessment of "horizontal resolution", since this component of the requirements is met by the network, not by any individual station/platform.

3.2.3.4 **Members shall nominate an observing station/platform for inclusion in RBON only if it makes observations available for international exchange in real time or near-real time.**

3.2.3.5 **Members shall nominate an observing station/platform for inclusion in RBON only if there is a commitment to operate it for at least four (4) years.**

Notes:
1. Sustainability over at least a ten-year period is recommended, see 2.2.1.2.
2. For fixed stations/platforms, the commitment is to observe at the nominated location, whereas for mobile types the commitment is to sustain a nominated density of observations over a given domain (point, line, area or volume) that may be achieved by (a) controlling the movement of a group of stations/platforms, for example, by relocations, or (b) periodic deployment of new mobile stations/platforms within the given domain.
3. Four years is the current cycle of a major review of RBON. This may change in the future.

3.2.3.6 **Members shall design RBONs in response to user observational requirements as compiled in the OSCAR/Requirements database, in consideration of regional needs.**

Notes:
1. Section 2.2 contains general provisions for the design of WIGOS and its components, including RBON, in response to user requirements.
2. The design principles specified in Appendix 2.1 and the non-satellite parts of Appendix 2.2 apply also to the design of the RBON.

3.2.3.7 **Members shall each nominate a set of stations/platforms to enable RBONs to meet, at threshold levels or better, the observational requirements of all WMO application areas.**

Notes:
1. The terms threshold, breakthrough and goal in the context of observational data requirements are defined in OSCAR and described further in Attachment 3.1.
2. When making their nominations, Members may take into account other WIGOS observations available within RBON and in addition to RBON such as space-based observations.
3. The relative priority given to different application areas and achieving performance significantly above the threshold levels may take account of regional priorities. However. there is a global priority to support numerical weather prediction (NWP) which in turn supports many other WMO applications.

3.2.3.8 Members should include in their set of stations/platforms nominated for the RBON, capabilities that enable RBONs to meet observational requirements of at least some application areas at the breakthrough level or better.

3.2.3.9 **Within their set of stations/platforms nominated for the RBON, Members shall include a subset consisting of stations/platforms that observe surface variables with an hourly or more frequent observing cycle, sufficient to meet the threshold observing cycle requirements of all application areas.**

Note: While a sufficient number of hourly-observation stations/platforms is needed to enable a RBON to meet the threshold observing cycle requirements of all application areas, further stations/platforms with a lower frequency of surface observations may also help the RBON to meet a number of other requirements.

3.2.3.10 Within their set of stations/platforms nominated for the RBON, Members should include enough stations/platforms that observe surface atmospheric pressure to enable the RBON to have horizontal resolution of 100 km or better for surface pressure observations.

Notes:
1. A desirable level of horizontal resolution for surface atmospheric pressure observations is 100 km or better. Such resolution would meet the breakthrough requirements for Global NWP and Climate Monitoring, and also the threshold requirements of some but not all WMO application areas.
2. This provision is most difficult to satisfy over remote areas and oceans, where efforts may be aided by automatic weather stations on land and at sea, and inclusion of atmospheric pressure observations from drifting buoys.

3.2.3.11 Within their set of stations/platforms nominated for the RBON, Members should include enough upper-air stations/platforms to enable the RBON to have horizontal resolution of 100 km or better for horizontal wind profile observations.

Notes:

1. A desirable level of horizontal resolution for wind (horizontal) profile observations is 100 km or better in the following domains: lower troposphere, high troposphere, and lower stratosphere. Such resolution would meet the breakthrough requirements for Global NWP and Climate Monitoring (GCOS) and also the threshold requirements of several other WMO application areas.
2. Although RBONs may provide tropospheric wind (horizontal) profile observations from a range of technologies, only balloon-tracking systems provide profiles in the lower stratosphere. Typically, these are radiosonde systems.
3. This provision is most difficult to satisfy in the lower stratosphere and over remote areas and oceans. Efforts in remote areas may be aided by the use of automatic systems including radar wind profilers and aircraft meteorological stations. For profile observations in the lower stratosphere, efforts may be aided by the use of automatic balloon release systems and participation in Automated Shipboard Aerological Programmes (ASAPs) with the cooperation of voluntary ships and research vessels.

3.2.3.12 Within their set of stations/platforms nominated for the RBON, Members should include enough weather radars to enable the RBON to improve Global NWP for precipitation and wind in geographical areas where such improvements bring socioeconomic benefits.

3.2.3.13 **Members shall nominate their proposed contributions to the RBON in their respective region for approval by the regional association or, in the case of the Antarctic, the WMO Executive Council or Congress.**

Notes:

1. Each regional association and the WMO Executive Council may wish to maintain a working body whose role includes compilation and analysis of nominations from Members, identification of gaps or deficiencies in the resulting RBON design compared to user requirements, and an action plan to deal with such gaps, so that it can make informed decisions about the RBON at its sessions.
2. Each regional association and the WMO Executive Council need to maintain detailed technical coordination with INFCOM.
3. Only stations/platforms registered in OSCAR can be nominated.

3.2.3.14 Members should work together in their regional association to identify and address gaps in their RBON, or in the WMO Executive Council in the case of the Antarctic.

Notes:

1. Guidance on the priority to be given to different types of gap may be found in the Statements of Guidance (SOGs) produced by the RRR, as described in Appendix 2.3 and available on the WMO website at https://community.wmo.int/rolling-review-requirements-process.
2. The general provisions for capacity development laid out in section 2.7.1 are relevant.

3.2.3.15 **Members shall contribute to the regular review of the composition of the RBON to address evolving requirements for observations.**

Note: Regular may be interpreted as at least once between sessions of the regional association or, in the case of the Antarctic, between sessions of Congress.

3.2.3.16 Members should request the president of the regional association, or the president of WMO in the case of the Antarctic, that minor amendments be made to the composition of the RBON whenever they are required.

Notes:

1. The process for dealing with such a request is specified by each regional association or, in the case of the Antarctic, by the WMO Executive Council. In general, the president of the regional association or the president of WMO approve, at the request of the Member concerned, on the advice of the chair of the respective subsidiary body and in consultation with the Secretary-General, minor amendments to the RBON. Any change of substance would still require the formal agreement of Members of the respective Region or of those Members operating components of the RBON in the Antarctic.

2. A minor amendment is not one of substance, that is, not one that would adversely affect the density of the network or cause a significant change in observational hours.
3. Regional practices are described further in the *Guide to the WMO Integrated Global Observing System* (WMO-No. 1165).
4. Members are notified of changes by the WMO Secretariat through the Operational Newsletter or by circular letter.

3.2.3.17 Members working together in the regional association, or the WMO Executive Council in the case of the Antarctic, shall routinely monitor RBON performance across the network to identify non-conformance with the designed performance.

Notes:
1. As indicated in 3.2.3.3–3.2.3.6 above, RBON is designed to respond to requirements for observations of the WMO application areas.
2. A regional association may wish to undertake this task through a Regional WIGOS Centre (RWC), as described in the *Guide to the WMO Integrated Global Observing System* (WMO-No. 1165), Chapter 8. A key source of information are global/regional centres undertaking a WIGOS Quality Monitoring Function.
3. Guidance on data quality monitoring, evaluation and incident management is detailed in the *Guide to the WMO Integrated Global Observing System* (WMO-No. 1165), Chapter 9. Note, in particular, the description of the WIGOS Data Quality Monitoring System.

3.2.3.18 Members shall acknowledge, document and rectify any identified non-conformance at one of their stations/platforms within time frames agreed by the respective regional association or, in the case of the Antarctic, by the WMO Executive Council or Congress.

Notes:
1. Where rectification actions extend over a long period, the Member is to provide regular reports on progress.
2. When an identified non-conformity persists, the president of the regional association, or President of WMO, may review the likelihood of rectification and, in consultation with the relevant Member, decide whether to remove the station/platform from the RBON between sessions of the regional association, or the Executive Council.
3. Details of relevant processes are provided in the *Technical Guidelines for Regional WIGOS Centres on the WIGOS Data Quality Monitoring System* (WMO-No. 1224).

3.3 INSTRUMENTATION AND METHODS OF OBSERVATION

3.3.1 General requirements

3.3.1.1 Members shall classify their surface meteorological and climatological observing stations on land.

Note: The *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume I, Chapter 1, 1.1.2, and Annex 1.D, defines a classification scheme for surface observing sites on land indicating their representativeness for the measurement of different variables. The content of Annex 1.D will be included as an appendix in a future edition of the present Manual.

3.3.1.2 Members should locate each observing station at a site that permits instrument exposure in line with the requirements of the specific application and also enables satisfactory non-instrumental observations.

Notes:
1. The *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume I, Chapter 1, Annexes 1.D and 1.F, provides further guidelines.
2. Requirements for GAW stations are formulated in section 6.

3.3.1.3 **Members shall accurately ascertain the position of a station referring to the World Geodetic System 1984 (WGS-84) and its Earth Geodetic Model 1996 (EGM96).**

Notes:
1. Guidelines are provided in the *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume I, Chapter 1, 1.3.3.2.
2. The WGS-84 is currently not in general use in hydrology. Its description will be included as an appendix in a future edition of the present Manual.

3.3.1.4 **Members shall define the elevation of the station.**

Note: The *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume I, Chapter 1, 1.3.3.2(c), specifies how to define the elevation of a station. This material will be included as an appendix in a future edition of the present Manual.

3.3.1.5 **If a station is located at an aerodrome, Members shall specify the official elevation of the aerodrome in accordance with the *Technical Regulations* (WMO-No. 49), Volume II.**

3.3.1.6 Members operating Regional Instrument Centres should follow the relevant specifications concerning capabilities and corresponding functions.

Note: The *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume I, Annex 1.C, specifies capabilities and corresponding functions for Regional Instrument Centres. This material will be included as an appendix in a future edition of the present Manual.

3.3.1.7 Members operating regional marine instrument centres should follow the relevant specifications concerning capabilities and corresponding functions.

Note: The *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume III, Chapter 4, Annex 4.A, specifies capabilities and corresponding functions for operating regional marine instrument centres. This material will be included as an appendix in a future edition of the present Manual.

3.3.2 Requirements for instruments

3.3.2.1 **Members shall avoid the use of mercury in their observing systems. Where mercury is still in use, Members shall define and obey appropriate safety precautions.**

Note: The *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume I, Chapter 3, Annex 3.A, provides safety precautions for the use of mercury. This material will be included as an appendix in a future edition of the present Manual.

3.3.2.2 For the inflation of meteorological balloons, Members should prefer helium over hydrogen. **If hydrogen is used, however, Members shall define and obey the appropriate safety precautions.**

Note: The *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume III, Chapter 8, 8.6, provides safety precautions for the use of hydrogen. This material will be included as an appendix in a future edition of the present Manual.

3.3.2.3 **Members shall calibrate all pyrheliometers, other than absolute pyrheliometers, by comparison, using the sun as the source, with a pyrheliometer that is traceable to the World Standard Group and has a likely uncertainty of calibration equal to or better than the pyrheliometer being calibrated.**

Note: The *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume I, Chapter 7, 7.2.1.4, provides detailed guidelines on the calibration of pyrheliometers.

3.3.2.4 Members shall regularly calibrate and ensure traceability of observations from their barometers according to the specified practices.

Note: The *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume I, Chapter 3, 3.6, highlights the importance of the atmospheric pressure observations and provides relevant guidance.

3.4 OPERATIONS

3.4.1 General requirements

Members operating surface-based observing systems shall follow the provisions of section 2.4.1.

3.4.2 Observing practices

3.4.2.1 Members shall ensure that the exposure, when applicable, of instruments for the same type of observation at different stations is similar so that observations may be compatible.

3.4.2.2 Members shall determine a reference height for each surface observing station or system.

Note: A reference height is defined as follows:

(a) Elevation of the station: it is the datum level to which barometric pressure reports at the station refer; such current barometric values are termed "station pressure" and are understood to refer to the given level for the purpose of maintaining continuity in the pressure records;

(b) For stations not located on aerodromes: elevation (height above mean sea level) of the ground on which the rain gauge stands or, if there is no rain gauge, of the ground beneath the thermometer screen. If there is neither rain gauge nor screen, it is the average level of terrain in the immediate vicinity of the station, expressed in metres rounded up to two decimals;

(c) For stations located on aerodromes it is the official altitude of the aerodrome.

3.4.3 Quality control

Members operating surface-based observing systems shall follow the provisions of section 2.4.3.

3.4.4 Data and metadata reporting

Members operating surface-based observing systems shall follow the provisions of section 2.4.4.

3.4.5 Incident management

Members operating surface-based observing systems shall follow the provisions of section 2.4.5.

3.4.6 Change management

Members should compare observations from new instruments over an extended interval before the old measurement system is taken out of service or when there has been a change of site. Where this procedure is impractical at all sites, Members should carry out comparisons at selected representative sites.

Notes:
1. This does not apply to all types of station; among the exceptions are hydrological stations.
2. Further details, including the required minimum intervals for such comparison, can be found in the *Guide to Climatological Practices* (WMO-No. 100), 2.6.7.

3.4.7 Maintenance

Observing sites and instruments should be maintained regularly so that the quality of observations does not deteriorate significantly between station inspections.

Note: Detailed guidance on maintenance of observing sites, observing systems and instruments is given in the *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volumes I, III and V, and the *Guide to Hydrological Practices* (WMO-No. 168), Volume I, 2.5.4 and 9.8.4.

3.4.8 Inspection and supervision

3.4.8.1 **Members shall arrange for their surface observing sites, stations and systems to be inspected at sufficiently frequent intervals to ensure that a standard of observations that meets its defined uncertainties is maintained, that instruments and all their indicators are functioning correctly, and that the exposure relevant to the instrument measurements has not changed significantly.**

Notes:
1. Detailed guidance on inspection, including frequency, is given in the Guide to Instruments and Methods of Observation (WMO-No. 8), Volume I, Chapter 1, 1.3.5; Volume III, Chapter 1, 1.7; Volume V, Chapter 1, 1.10.1, and Chapter 4, 4.3.4.
2. Reference is made to the *Technical Regulations* (WMO-No. 49), Volume II, for provisions on the inspection of aeronautical meteorological stations including its frequency.

3.4.8.2 **Members shall ensure that the inspection is performed by qualified and adequately trained staff.**

3.4.8.3 When performing inspections, Members should ensure that:

(a) The siting, selection and installation, as well as exposure when applicable, of instruments are known, recorded and acceptable;

(b) Instruments have approved characteristics, are in good order and regularly checked against relevant standards;

(c) There is uniformity in the methods of observation and in the procedure for any reduction of observations.

Note: Detailed guidance on inspection and supervision of observing systems and sites is given in the *Guide to Instruments and Methods of Observation* (WMO-No. 8), which includes guidelines on GAW measurements (see Volume I, Chapter 16), the *Guide to Hydrological Practices* (WMO-No. 168), Volume I, 2.5.3, 2.5.5, 8.7 and 9.8.4, and the *Manual on Stream Gauging* (WMO-No. 1044), Volume I, 4.4 and 4.8.

3.4.9 Calibration procedures

Members operating surface-based observing systems shall follow the provisions of section 2.4.9.

3.5 OBSERVATIONAL METADATA

Note: Detailed guidance regarding the establishment, maintenance and update of metadata records is given in the *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume I, Chapter 1, 1.1.3 and 1.3.4; the *Guide to Climatological Practices* (WMO-No. 100), 2.5 and 2.6.9; the *Guide to the Global Observing System* (WMO-No. 488), Appendix III.3; and the *Guide to Hydrological Practices* (WMO-No. 168), Volume I, Chapter 10.

Members operating surface-based observing systems shall follow the provisions of section 2.5.

Note: Further provisions specific to the WIGOS component observing systems appear in sections 5, 6, 7 and 8.

3.6 QUALITY MANAGEMENT

Members operating surface-based observing systems shall follow the provisions of section 2.6.

Note: Further provisions specific to the WIGOS space-based subsystem appear in section 4; those specific to the WIGOS component observing systems appear in sections 5, 6, 7 and 8.

3.7 CAPACITY DEVELOPMENT

Members operating surface-based observing systems shall follow the provisions of section 2.7.

Note: Further provisions specific to the WIGOS space-based subsystem appear in section 4; those specific to the WIGOS component observing systems appear in sections 5, 6, 7 and 8.

ATTACHMENT 3.1. THE RANGE OF REQUIREMENTS FOR OBSERVATIONS OF THE WMO APPLICATION AREAS

1. Introduction

Note: One of the three components of the Observing Systems Capability Analysis and Review (OSCAR) tool is a database of requirements for observations. This database is a work in progress and must be interpreted with care. At the start of 2018, some requirements still needed to be added and some existing requirements are now outdated and need to be revised. All OSCAR information provided in this attachment is for illustrative purposes only and must be checked in the latest version of OSCAR available online before further use.

A requirement consists of a specification by one WMO application area of a specific physical variable to be observed, in a specific domain (vertical layer and horizontal coverage), with a performance level quantified in terms of up to six criteria:

- Uncertainty (see note below)
- Horizontal resolution
- Vertical resolution
- Observing cycle
- Timeliness
- Stability.

Note: The OSCAR/Requirements database represents the uncertainty as 1σor 68% confidence interval, which is not in line with international standard practice. The international standard practice is to use 95% confidence interval which is 2$\sigma$for a standard normal distribution. It was adopted by WMO by mutual agreement with the International Bureau of Weights and Measures (BIPM), and was developed by the Joint Committee for Guides in Metrology (JCGM). It is published as *Evaluation of measurement data -Guide to the expression of uncertainty in measurement* (JCGM 100, 2008), a document shared by the JCGM member organizations (BIPM, the International Electrotechnical Commission (IEC), the International Federation of Clinical Chemistry and Laboratory Medicine (IFCC), the International Laboratory Accreditation Cooperation (ILAC), the International Organization for Standardization (ISO), the International Union of Pure and Applied Chemistry (IUPAC), the International Union of Pure and Applied Physics (IUPAP) and the International Organization of Legal Metrology (OIML). Further explanation and details on its use in meteorology are provided in the *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume I, Chapter 1, 1.6.

Each of the fifteen WMO application areas requires only some of the approximately 300 physical variables and in only some of the domains. A total of about 600 requirements is listed in OSCAR.

Where multiple WMO application areas require observations of the same physical variable in the same domain, they generally have different performance requirements.

Where a WMO application area requires observations of multiple physical variables in the same domain, there are often different required performance levels in horizontal and vertical resolution, observing cycle and timeliness.

The remaining sections of this attachment convey the structure used to describe performance levels, some examples of requirements and an illustration of how the requirements for observing cycle, horizontal resolution, timeliness and uncertainty vary between WMO application areas for a given variable and between variables for a given WMO application area.

2. Performance levels

Each requirement from a WMO application area for observation of a physical variable includes a description of the required performance level, using some or all of six criteria listed in section 1 of this attachment, as appropriate.

For each criterion, three values are specified, representing respectively the "threshold", "breakthrough" and "goal" levels of performance. These levels may be described as follows:

- "Threshold" is the minimum requirement to be met to ensure that the observation is useful;
- "Breakthrough" is an intermediate level between "threshold" and "goal" which, if achieved, would result in a significant improvement for the particular application that registered the requirement;
- "Goal" is an ideal requirement above which further improvements are not necessary.

3. Examples of requirements of application areas for observations of physical variables

The best way to assess the value of an observation is to consider the required level of performance against all six criteria when observing one variable in one domain for a single application area.

An example is provided in Table 1. For observations of air temperature (at surface) across the global domain to be of any value to the Climate Monitoring application area, the threshold level of performance must be achieved across all criteria, that is:

- Uncertainty equal to or less than 0.3 K;
- Horizontal resolution equal to or better than 100 km;
- Observing cycle equal to or shorter than 12 hours;
- Timeliness equal to or better than 2 days.

While many stations in the RBON might satisfy the observing cycle and timeliness threshold levels, only those that also satisfy the uncertainty requirement have any usefulness for this application.

Table 1. Summary of Requirement #70 from the OSCAR database, which is the requirement of the Climate Monitoring application area for observations of air temperature (at surface) across the global domain.

	Goal	*Breakthrough*	*Threshold*
Uncertainty	0.1 K	0.15 K	0.3 K
Stability/decade (if applicable)			
Horizontal Resolution	25 km	50 km	100 km
Vertical Resolution			
Observing Cycle	3 h	6 h	12 h
Timeliness	24 h	36 h	2 d

Another example is provided in Table 2. For observations of atmospheric temperature in the lower troposphere across the global domain to be of any value to the High-resolution NWP application area, the threshold level of performance must be achieved across all criteria, that is:

- Uncertainty equal to or less than 3 K;
- Horizontal resolution equal to or better than 10 km;
- Vertical resolution equal to or better than 1 km;
- Observing cycle equal to or shorter than 6 hours;
- Timeliness equal to or better than 2 hours.

Only those reports of upper-air temperature that are repeated at least four times per day have any value for this application area, even if they satisfy the other performance criteria.

Table 2. Summary of Requirement #341 from the OSCAR database, which is the requirement of the High-resolution NWP application area for observations of atmospheric temperature in the lower troposphere across the global domain.

	Goal	*Breakthrough*	*Threshold*
Uncertainty	0.5 K	1 K	3 K
Stability/decade (if applicable)			
Horizontal resolution	0.5 km	2 km	10 km
Vertical resolution	0.1 km	0.25 km	1 km
Observing cycle	15 min	60 min	6 h
Timeliness	15 min	30 min	2 h

Further assessment of the value of an observation can be made by considering how many requirements from different application areas it satisfies. The tables in sections 4 and 5 below help to illustrate the spectrum of requirements across different application areas and across different variables.

4. Examples of requirements for observing cycle, horizontal resolution, timeliness and uncertainty, highlighting differences between application areas for a given variable

Table 3 shows a wide range of observing cycle requirements for surface-air temperature across the different application areas. Hourly observations are required to ensure that the threshold requirements of all application areas are satisfied. Hourly observations would also satisfy the breakthrough requirements of all but the Nowcasting/Very-short Range Forecasting (VSRF) application area.

Table 3. Air temperature at surface: observing cycle requirements for different application areas

Variable: Air temperature at surface
Domain: Atmosphere, near surface
Coverage: Global or global ocean, except for Aeronautical Meteorology (point at the aerodrome)

Criterion: Observing cycle	*Threshold*	*Required performance level: Breakthrough*	*Goal*
24 hours	Agricultural Meteorology		
12 hours	Global NWP Climate Monitoring[a]	Agricultural Meteorology[b]	
6 hours	High-resolution NWP	Global NWP Climate Monitoring	
3 hours	Ocean Applications Aeronautical Meteorology		Climate Monitoring
60 minutes	Nowcasting/VSRF	High-resolution NWP Ocean Applications Aeronautical Meteorology	Global NWP Agricultural Meteorology
30 minutes		Nowcasting/VSRF	High-resolution NWP Ocean Applications Aeronautical Meteorology
10 minutes			Nowcasting/VSRF

Notes:

[a] The names of the application areas are taken from OSCAR/Requirements, apart from Climate Monitoring which replaces AOPC.

[b] Agricultural meteorology breakthrough requirement is recorded as 15 hours.

Table 4 shows that for lower tropospheric wind (horizontal), Aeronautical Meteorology has the most demanding observing cycle requirements. A 10-minute observing cycle (the threshold level) is required for observations to have any value for this application. However, a 3-hour observing cycle would ensure that the observation has some value for all other applications and significant value (breakthrough level of performance) for several applications including Global NWP. A 12-hour observing cycle would be sufficient to provide some value for Global NWP, High-resolution NWP and Ocean Applications. A 24-hour or longer observing cycle would have limited value.

Table 4. Lower tropospheric wind (horizontal): observing cycle requirements for different application areas

Variable: Wind (horizontal)
Domain: Atmosphere, lower troposphere
Coverage: Global

Criterion: Observing cycle	*Threshold*	*Required performance level: Breakthrough*	*Goal*
24 hours	Ocean Applications		
12 hours	Global NWP High-resolution NWP		
6 hours	Climate Monitoring[a]	Global NWP	
3 hours	Nowcasting/VSRF	Climate Monitoring[b] Ocean Applications	Climate Monitoring
60 minutes		High-resolution NWP	Global NWP
30 minutes		Nowcasting/VSRF	
15 minutes			High-resolution NWP
10 minutes	Aeronautical Meteorology		
5 minutes		Aeronautical Meteorology[c]	Nowcasting/VSRF Ocean Applications[d] Aeronautical Meteorology

Notes:

[a] The names of the application areas are taken from OSCAR/Requirements, apart from Climate Monitoring which replaces AOPC.

[b] Climate monitoring breakthrough requirement is recorded as 4 hours.

[c] Aeronautical meteorology breakthrough requirement is recorded as 7 minutes.

[d]. Ocean applications goal requirement is recorded as 6 minutes.

Table 5 highlights the importance of uncertainty when observing surface-air temperature for Climate Monitoring application, which require at least 0.3 K and ideally 0.1 K uncertainty. Many other applications gain value from observations having uncertainties as large as 2.0 K.

Table 5. Air temperature at surface: uncertainty requirements for different application areas

Variable: Air temperature at surface
Domain: Atmosphere, near surface
Coverage: Global

Criterion: Observing cycle	*Threshold*	*Required performance level: Breakthrough*	*Goal*
2.0 K	Global NWP High-resolution NWP Nowcasting/VSRF		
1.0 K	Ocean Applications	Global NWP	
0.80 K		High-resolution NWP	
0.70 K		Nowcasting/VSRF	
0.50 K		Ocean Applications	Global NWP High-resolution NWP Nowcasting/VSRF
0.30 K	Climate Monitoring[a]		
0.10 K		Climate Monitoring[b]	Ocean Applications Climate Monitoring

Notes:

[a] The names of the application areas are taken from OSCAR/Requirements, apart from Climate Monitoring which replaces AOPC.

[b] Climate monitoring breakthrough requirement is 0.15 K.

Table 6 shows a range of timeliness requirements for surface atmospheric pressure. Observations lose their value most rapidly for aeronautical meteorology, whose threshold level indicates the observation must be available within 30 minutes to have any value and within 10 minutes to have more significant value (the breakthrough level).

Table 6. Atmospheric pressure at surface: timeliness requirements for different application areas

Variable: Atmospheric pressure at surface
Domain: Atmosphere, near surface
Coverage: Global or Global ocean

Criterion: Timeliness	*Threshold*	*Required performance level: Breakthrough*	*Goal*
12 hours	Climate Monitoring[a] Ocean Applications-B[b]		
6 hours	Global NWP	Climate Monitoring Ocean Applications-B	
3 hours			Climate Monitoring Ocean Applications-B
2 hours	High-resolution NWP Ocean Applications-A		
60 minutes		Ocean Applications-A	
30 minutes	Aeronautical Meteorology	Global NWP High-resolution NWP	Ocean Applications-A
15 minutes			High-resolution NWP
10 minutes		Aeronautical Meteorology	
5 minutes			Global NWP[c] Aeronautical Meteorology

Notes:

[a] The names of the application areas are taken from OSCAR/Requirements, apart from Climate Monitoring which replaces AOPC.

[b] The Ocean Application area has provided two sets of requirements: A: Ocean forecasting (coastal), and B: Maritime safety services.

[c] Global NWP Goal requirement is 6 minutes.

Table 7 highlights the wide range of requirements for the horizontal resolution of lower tropospheric wind (horizontal) observations. The very demanding requirements of High-resolution NWP and Nowcasting/VSRF applications, even at the threshold level, are likely to be satisfied by RBONs only in very limited domains but not in regional or global domains. In this case, the design of RBONs would need to take into account how its surface stations/ platforms could complement the lower tropospheric wind (horizontal) observations from space.

Table 7. Lower tropospheric wind (horizontal): horizontal resolution requirements for different application areas

Variable: Wind (horizontal)
Domain: Atmosphere, lower troposphere
Coverage: Global

Criterion: Horizontal resolution	*Threshold*	*Required performance level: Breakthrough*	*Goal*
500 km	Climate Monitoring[a] Global NWP		
200 km	Ocean Applications	Climate Monitoring	
100 km	Aeronautical Meteorology	Global NWP	Climate Monitoring
70 km		Aeronautical Meteorology	
50 km		Ocean Applications	Aeronautical Meteorology
20 km	Nowcasting/VSRF		
15 km			Global NWP
10 km	High-resolution NWP		Ocean Applications
5 km		Nowcasting/VSRF	
2 km		High-resolution NWP	
1 km			Nowcasting/VSRF
0.5 km			High-resolution NWP

[a] The names of the application areas are taken from OSCAR/Requirements, apart from Climate Monitoring which replaces AOPC.

5. Examples of requirements for observing cycle and horizontal resolution, highlighting differences between variables for a given application area

Aeronautical Meteorology has specified requirements for observations of 36 physical variables, of which 14 have specified performance requirements for an observing cycle. A representative subset consisting of 8 of those 14 variables is included in Table 8, illustrating the range of different observing cycle requirements for different variables.

Table 8. Aeronautical meteorology: observing cycle requirements for different physical variables

Application area: Aeronautical Meteorology

Criterion: Observing cycle	*Threshold*	*Required performance level: Breakthrough*	*Goal*
3 hours	Temperature: LT, HT, LS[a] Specific humidity: LT		
2 hours	Atmospheric pressure at surface (sfc) Precipitation type (at sfc)		
90 minutes		Temperature: LT, HT, LS Specific humidity: LT	
60 minutes		Atmospheric pressure (at sfc) Precipitation type (at sfc)	Temperature: LT, HT, LS Specific humidity: LT
30 minutes			Atmospheric pressure (at sfc) Precipitation type (at sfc)
10 minutes			
5 minutes			
2 minutes	Meteorological optical range (at sfc) Wind gust (at sfc) Wind speed (at sfc) Wind vector (at sfc)[b]		
60 seconds		Wind gust (at sfc) Wind speed (at sfc) Wind vector (at sfc)	
30 seconds		Meteorological optical range (at sfc)[c]	
5 seconds			Wind gust (at sfc) Wind speed (at sfc) Wind vector (at sfc)

Notes:

[a] LT = lower troposphere; HT = higher troposphere; LS = lower stratosphere;

[b] The coverage specified for Meteorological optical range (at surface), wind gust (at sfc), wind speed (at sfc) and wind vector (at sfc) is point only at aerodromes, while global coverage is required for the other variables;

[c] The requirement for Meteorological optical range (at surface) is actually 108 seconds (threshold) and 36 seconds (breakthrough) while no goal level is specified.

High-resolution NWP has specified requirements for observations of 56 physical variables, all with specified performance requirements for horizontal resolution. A representative subset consisting of 23 of those 56 variables is included in Table 9, illustrating the range of different horizontal resolution requirements for different variables.

Table 9. High-resolution NWP: horizontal resolution requirements for different physical variables

Application area: High-resolution NWP

Criterion: Horizontal resolution	*Threshold*	*Required performance level: Breakthrough*	*Goal*
100 km	Wind (horizontal): LS[a] Temperature: LS Ozone: LS		
40 km	Wind vector (at sfc[a]) Atmospheric pressure (at sfc) Ozone (total column) Sea-ice thickness Soil moisture Dominant wave period Leaf Area Index		
30 km	Specific humidity: HT[a]		
25 km	Temperature: HT	Wind (horizontal): LS Temperature: LS	
20 km	Wind (horizontal): HT Wind speed (at sfc) Temperature (at sfc) Specific humidity: LT[a] Specific humidity (at sfc)	Ozone: LS	
10 km	Wind (horizontal): LT Temperature: LT Precipitation intensity (at sfc) Cloud cover Cloud type	Wind (horizontal): HT Wind vector (at sfc) Specific humidity: HT Atmospheric pressure (at surface) Ozone (total column) Sea-ice thickness Dominant wave period	Wind (horizontal): LS Temperature: LS
5 km	Precipitation type (at sfc)	Wind speed (at sfc) Temperature: HT Temperature (at sfc) Specific humidity: LT Specific humidity (at sfc) Soil moisture Leaf Area Index	Ozone: LS Dominant wave period
2 km		Wind (horizontal): LT Temperature: LT Precipitation intensity (at sfc) Cloud cover Cloud type	Wind (horizontal): HT Wind vector (at sfc) Specific humidity: HT Atmospheric pressure (at sfc) Ozone (total column) Sea-ice thickness
1 km		Precipitation type (at sfc)[b]	Temperature: HT Temperature (at sfc) Specific humidity (at sfc) Soil moisture Leaf Area Index

Criterion: Horizontal resolution	*Threshold*	*Required performance level: Breakthrough*	*Goal*
0.5 km			Wind (horizontal): LT Wind speed (at sfc) Temperature: LT Specific humidity: LT Precipitation intensity (at sfc) Cloud cover Cloud type
0.25 km			Precipitation type (at sfc)

Notes:

[a] LS = lower stratosphere; LT = lower troposphere; HT = higher troposphere; sfc = surface;

[b] Precipitation type (at sfc) breakthrough level is 1.5 km.

4. ATTRIBUTES SPECIFIC TO THE SPACE-BASED SUBSYSTEM OF WIGOS

4.1 REQUIREMENTS

4.1.1 General

Members shall strive to develop, implement and operate a space-based environmental observing system in support of WMO Programmes as described in Attachment 4.1.

Note: The space-based subsystem of WIGOS is established through dedicated satellites, remotely observing the characteristics of the atmosphere, the earth and the oceans.

4.1.2 Observed variables

This subsystem shall provide quantitative data enabling, independently of or in conjunction with surface-based observations, the determination of variables including but not limited to:

(a) Three-dimensional fields of atmospheric temperature and humidity;

(b) Temperature of sea and land surfaces;

(c) Wind fields (including ocean surface winds);

(d) Cloud properties (amount, type, top height, top temperature and water content);

(e) Radiation balance;

(f) Precipitation (liquid and frozen);

(g) Lightning;

(h) Ozone concentration (total column and vertical profile);

(i) Greenhouse gas concentration;

(j) Aerosol concentration and properties;

(k) Volcanic ash cloud occurrence and concentration;

(l) Vegetation type and status, and soil moisture;

(m) Flood and forest fire occurrence;

(n) Snow and ice properties;

(o) Ocean colour;

(p) Wave height, direction and spectra;

(q) Sea level and surface currents;

(r) Sea-ice properties;

(s) Solar activity;

(t) Space environment (electric and magnetic field, energetic particle flux and electron density).

Note: Information regarding the current capabilities of the space-based subsystem is available through the OSCAR tool at https://community.wmo.int/oscar and https://community.wmo.int/oscar-wmo-observational-requirements-and-capabilities.

4.1.3 Observing performance requirements

Satellite operators providing observational data to WIGOS shall strive to meet, to the extent possible, the uncertainty, timeliness, temporal and spatial resolution, and coverage requirements of WIGOS as defined in the WIR, based on the Rolling Review of Requirements described in section 2.

Notes:

1. In the present Manual, the term "satellite operators" refers to Members or a coordinated group of Members operating environmental satellites.
2. A coordinated group of Members operating environmental satellites acts jointly to operate one or more satellites through an international space agency such as the European Space Agency or the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT).
3. These requirements are recorded and maintained in the requirements database available at https://community.wmo.int/oscar and https://community.wmo.int/oscar-wmo-observational-requirements-and-capabilities.

4.1.4 Global planning

Satellite operators shall cooperate to ensure that a constellation of satellite systems is planned and implemented to guarantee the continuous provision of space-based observations in support of WMO Programmes.

Note: Collaboration is pursued within the Coordination Group for Meteorological Satellites (CGMS), which includes all Members operating space-based observation systems in support of WMO Programmes.

4.1.5 Continuity

4.1.5.1 Satellite operators working together under the auspices of CGMS or otherwise, should ensure the continuity of operation and sustained data dissemination and distribution services of the operational satellites within the subsystem, through appropriate contingency arrangements and relaunch plans.

4.1.5.2 Satellite operators should strive to maintain space-based assets beyond design lifetime if they provide added observations on an affordable basis.

4.1.6 Overlap

Satellite operators should ensure an adequate period of overlap of new and old satellite systems in order to determine inter-satellite instrumental biases and maintain the homogeneity and consistency of time series observations, unless reliable transfer standards are available.

4.1.7 Interoperability

4.1.7.1 Satellite operators shall achieve the greatest possible interoperability of their different systems.

4.1.7.2 **Satellite operators shall make available sufficient technical details about the instruments, data processing, transmissions and dissemination schedules for Members to fully exploit the data.**

4.2 DESIGN, PLANNING AND EVOLUTION

Note: The space-based subsystem is composed of:
(a) An Earth observation space segment;
(b) An associated ground segment for data reception, processing, dissemination and stewardship;
(c) A user segment.

4.2.1 Space segment architecture

Note: The overall architecture of the space segment is described in Attachment 4.1. It is defined and evolves in consultation with CGMS.

It includes:

(a) A constellation of geostationary satellites;

(b) A core constellation of sun-synchronous satellites distributed over three separate orbital planes;

(c) Other operational satellites operated on either sun-synchronous orbits or other appropriate low Earth orbits;

(d) Research and development satellites on appropriate orbits.

4.2.2 Space programme life cycles

Satellite operators shall consider a trade-off between the need for a long series to meet the development cost and the user learning curve, on one hand, and the need to develop a new generation in order to benefit from state-of-the-art technology, on the other hand.

Notes:
1. The development of an operational satellite programme is conducted in several phases including: definition of user requirements, feasibility assessment at system level, preliminary design, detailed design, development and testing of the subsystems, integration of all subsystems, system testing, launch campaign and on-orbit commissioning. The overall duration of these development phases is typically of the order of 10 to 15 years.
2. The exploitation phase for an operational programme including a series of recurring satellites is typically of the order of 15 years.

4.3 INSTRUMENTS AND METHODS OF OBSERVATION

Notes:
1. Space-based observation relies on a wide range of sensor types, for example, active or passive, operating in various spectral ranges, and with various scanning or pointing modes. Information on the principles of Earth observation from space, the different types of space-based instrument and the derivation of geophysical variables from space-based measurements can be found in the *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume IV, Chapter 5.
2. Detailed characteristics of current and planned systems of environmental satellites are available in the satellite module of the OSCAR tool, which is available on line (https://community.wmo.int/oscar-wmo-observational-requirements-and-capabilities). It also contains an indication of the main instruments that are relevant for each specific variable observable from space, with their potential performance for the respective variables.

4.3.1 Calibration and traceability

4.3.1.1 Satellite operators shall perform a detailed instrument characterization before launch.

Note: Members must strive to follow the pre-launch instrument characterization guidelines recommended by the Global Space-based Inter-calibration System.

4.3.1.2 After launch, satellite operators shall calibrate all instruments on a routine basis against reference instruments or calibration targets.

Notes:
1. Advantage should be taken of satellite collocation to perform on-orbit instrument intercomparison and calibration.
2. Calibration must be done in accordance with methodologies established and documented by the Global Space-based Inter-calibration System and the Committee on Earth Observation Satellites (CEOS) working group on calibration and validation.

4.3.1.3 Satellite operators shall provide calibrated data with complete and traceable estimates of stability and uncertainty that are linked to the International System of Units (SI) standards.

Note: The *Global Observing System for Climate: Implementation Needs*, GCOS-200) calls for the sustained measurement of key variables from space traceable to reference standards, and recommends conducting and evaluating a satellite climate calibration mission.

4.3.1.4 To ensure traceability to SI standards, satellite operators shall define a range of ground-based reference targets for calibration purposes.

4.4 SPACE SEGMENT IMPLEMENTATION

4.4.1 Operational satellites on Geostationary Earth Orbit

4.4.1.1 Satellite operators should implement an operational constellation of satellites in geostationary orbit as described in Attachment 4.1.

4.4.1.2 Satellite operators shall ensure that the constellation of satellites in geostationary orbit provides full disc imagery at least every 15 minutes and achieves coverage of all longitudes, throughout a field of view between 60° S and 60° N.

Note: This implies the availability of at least six operational geostationary satellites if located at evenly distributed longitudes, with in-orbit redundancy.

4.4.1.3 Satellite operators should implement rapid-scan capabilities where feasible and ensure that rapid-scan data are available to Members affected by natural disasters, in particular tropical cyclones and volcanic activity.

4.4.1.4 For the imagery mission in geostationary orbit, satellite operators should ensure an availability rate of rectified and calibrated data of at least 99% as a target.

4.4.1.5 To meet the essential requirements for the continuity of data delivery, satellite operators shall strive to implement contingency plans, involving the use of in-orbit standby flight models and rapid call-up of replacement systems and launches.

4.4.2 Core operational constellation on sun-synchronous low Earth orbits

4.4.2.1 Operators of low Earth orbit (LEO) satellites should implement a core operational constellation of satellites in three regularly distributed sun-synchronous orbits as described in Attachment 4.1.

4.4.2.2 Operators of the core constellation of environmental LEO satellites on three sun-synchronous orbital planes, in early morning, mid-morning and afternoon orbit, shall strive to ensure a high level of robustness to permit the delivery of imagery and sounding data from at least three polar orbiting planes, on not less than 99% of occasions.

Note: This implies provisions for a ground segment, instrument and satellite redundancy, and rapid call-up of replacement launches or in-orbit spares.

4.4.3 Other capabilities on low Earth orbits

Operators of environmental LEO satellites should implement capabilities in appropriate orbits as described in Attachment 4.1.

4.4.4 Research and development satellites

4.4.4.1 Operators of research and development satellites shall consider providing the following observing capabilities:

(a) Advanced observation of the parameters necessary to progress on the understanding and modelling of the water cycle, the carbon cycle, the energy budget and the chemical processes of the atmosphere;

(b) Pathfinders for future operational missions.

Note: For WMO, the main benefits of research and development satellite missions are:
(a) Support of scientific investigations of atmospheric, oceanic and other environment-related processes;
(b) Testing or demonstration of new or improved sensors and satellite systems in preparation for new generations of operational capabilities to meet WMO observational requirements.

4.4.4.2 Members shall strive to maximize the usefulness of observations from research and development satellites for operational applications. In particular, operators of research and development satellites shall make provisions, where possible, to enable near-real-time data availability to promote the early use of new types of observation for operational applications.

Notes:
1. Although neither long-term continuity of service nor a reliable replacement policy are assured, research and development satellites provide, in many cases, observations of great value for operational use.
2. Although they are not operational systems, research and development satellites have proven to support operational meteorology, oceanography, hydrology and climatology substantially.

4.5 GROUND SEGMENT IMPLEMENTATION

4.5.1 General

4.5.1.1 Satellite operators shall make observational data available to Members through the WMO Information System (WIS) in accordance with the provisions laid out in the *Manual on the WMO Information System* (WMO-No. 1060). Satellite operators shall inform Members of the means for obtaining these data through catalogue entries and shall provide sufficient metadata to enable meaningful use of the data.

4.5.1.2 **Satellite operators shall set up facilities for the reception of remote-sensing data (and data collection system data when relevant) from operational satellites, and for the processing of quality-controlled environmental observation information, with a view to further near-real-time distribution.**

4.5.1.3 **Satellite operators shall strive to ensure that data from polar-orbiting satellites are acquired on a global basis, without temporal gaps or blind orbits, and that data latency meets WMO timeliness requirements.**

4.5.2 Data dissemination

4.5.2.1 **Satellite operators shall ensure near-real-time dissemination of data sets, as per the requirements of Members, either by direct broadcast from the satellite, or by other means, such as rebroadcast, via telecommunication satellites.**

4.5.2.2 In particular, operators of operational sun-synchronous satellites providing the core meteorological imagery and sounding mission should ensure inclusion of a direct broadcast capability as follows:

(a) Direct broadcast frequencies, modulations and formats should allow a particular user to acquire data from the satellite with a standardized antenna and signal processing hardware. To the extent possible, the frequency bands allocated to meteorological satellites should be used;

(b) Direct broadcast should be provided through a high data rate stream, such as the High-resolution Picture Transmission (HRPT) or its subsequent evolution, to provide meteorological centres with all the data required for numerical weather prediction (NWP), nowcasting and other real-time applications;

(c) If possible, a low data rate stream should also be provided, such as the Low-rate Picture Transmission (LRPT), to convey an essential volume of data to users with lower connectivity or low-cost receiving stations.

4.5.2.3 **Satellite operators shall consider implementing rebroadcast via telecommunication satellites to complement and supplement direct broadcast services and to facilitate access to integrated data streams, including data from different satellites, to non-satellite data and to geophysical data products.**

4.5.2.4 **Operators of operational geostationary meteorological satellites with rapid-scan capabilities shall strive to provide meteorological centres with data in near-real time as required for nowcasting, NWP and other real-time applications.**

4.5.3 Data stewardship

4.5.3.1 **Satellite operators shall provide a full description of all processing steps taken in the generation of satellite data products, including algorithms, characteristics and outcomes of validation activities.**

4.5.3.2 Satellite operators should provide pre-operational data to users before formal data release.

4.5.3.3 **Satellite operators shall preserve long-term raw data records and ancillary data required for their calibration and reprocessing as appropriate, with the necessary traceability information to achieve consistent fundamental climate data records.**

4.5.3.4 **Satellite operators shall maintain and provide unrestricted access to Level 1B satellite data archives including all relevant metadata pertaining to the location, orbit parameters and calibration procedures used.**

Note: The data processing levels are described in the Earth Observing System Data and Information System of the US National Aeronautics and Space Administration (NASA) (https://earthdata.nasa.gov/collaborate/open-data-services-and-software/data-information-policy/data-levels).

4.5.3.5 **Satellite operators shall ensure that their archiving system is capable of providing on-line access to the archive catalogue with a browsing facility, that it provides adequate description of data formats and will allow users to download data.**

4.5.4 Data collection systems

4.5.4.1 **Satellite operators with a capability to receive data and/or products from data collection platforms (DCP) shall maintain technical and operational coordination under the auspices of CGMS in order to ensure compatibility.**

4.5.4.2 **Satellite operators shall maintain a number of international DCP channels, which should be identical on all geostationary satellites, to support the operation of mobile platforms moving across all individual geostationary footprints.**

4.5.4.3 **Satellite operators shall publish details of the technical characteristics and operational procedures of their data-collection missions, including the admission and certification procedures.**

4.5.5 The user segment

4.5.5.1 **Operators of research and development satellites shall implement capabilities enabling Members to access the data in one of the following ways: by downloading data from the server(s) or by receiving data from a rebroadcasting service or a direct broadcast capability.**

4.5.5.2 **Members shall endeavour to install and maintain in their territory at least one system enabling access to digital data from both LEO and geostationary operational satellite constellations: either a receiver of rebroadcast service providing the required information in an integrated way, or a combination of dedicated direct readout stations.**

4.5.5.3 Where appropriate, Members should strive to utilize fixed or moving DCP systems (for example, to cover data-sparse areas) to take advantage of the data-collection and relay capability of the environmental observation satellites.

4.6 OBSERVATIONAL METADATA

For each space-based system they operate, satellite operators shall record, retain and make available observational metadata in accordance with the provisions of section 2.5.

4.7 QUALITY MANAGEMENT

Satellite operators shall include appropriate quality indicators in the metadata for each dataset, in accordance with the provisions of section 2.6.

4.8 CAPACITY DEVELOPMENT

4.8.1 Centres of excellence

Satellite operators, and other Members having the capability to do so, shall provide support to the education and training of instructors in the use of satellite data and capabilities, at specialized Regional Training Centres or other training institutes designated as centres of excellence in satellite meteorology, in order to build up expertise and facilities at a number of regional growth points.

4.8.2 Training strategy

Satellite operators should focus their assistance, to the extent possible, on one or more of these centres of excellence within their service areas and contribute to the Virtual Laboratory for Education and Training in Satellite Meteorology (VLab).

Note: The aim of the education and training strategy implemented through the virtual laboratory is to systematically improve the use of satellite data applied for WMO application areas, with a focus on meeting the needs of developing countries.

4.8.3 User preparation for new systems

4.8.3.1 In order to facilitate a smooth transition to new satellite capabilities, satellite operators should take steps to prepare users through training, guidance on necessary upgrades of receiving equipment and processing software, and the provision of information and tools to facilitate the development and testing of user applications.

4.8.3.2 Satellite operators should provide information on planned and achieved data timeliness, data format and processing tools availability.

4.8.3.3 In addition to working through the virtual laboratory, Members should, as appropriate, exploit partnerships with organizations providing education and training in environmental satellite applications, depending on their specific needs.

4.8.4 Collaboration between users and satellite operators

4.8.4.1 In order to achieve the most effective utilization of satellite data, Members should pursue close collaboration between users and satellite operators at a regional level.

4.8.4.2 Satellite operators should engage with users and document potential impact on applications when developing new satellite systems, products, or ground systems.

4.8.4.3 Working with their regional association, Members should follow systematic steps to document the regional requirements for satellite data access and exchange.

ATTACHMENT 4.1. BASELINE CONTRIBUTION TO THE WMO INTEGRATED GLOBAL OBSERVING SYSTEM (WIGOS)

(Adopted at the forty-ninth meeting of the Coordination Group for Meteorological Satellites (CGMS-49), 19-21 May 2021)

1. INTRODUCTION

The Coordination Group for Meteorological Satellites (CGMS) provides a forum for the exchange of technical information on meteorological and environmental satellite systems as well as research and development missions in support of the World Meteorological Organization's (WMO) Rolling Review of Requirements (RRR), the IOC-UNESCO, and other users. The primary goal of the coordination activities is to support operational monitoring and forecasting of weather, space weather and the climate. CGMS coordinates satellite systems of its members in an end-to-end perspective including, but not limited to protection of on-orbit assets, support to users, and facilitation of shared access to satellite data and products.

1.1 Document purpose

The "Baseline" constitutes the commitments and plans of CGMS members to provide particular observations and services. CGMS members plan to maintain the capabilities and services described below to support the Global Observing System. This document will remain consistent with the principles of the *Vision for the WMO Integrated Global Observing System in 2040* (WMO-No. 1243) (hereafter the "WIGOS Vision"), and the WIGOS Vision serves as important input in the development of CGMS members' plans.

1.2 Reference documents

Table 1. Documents referenced in this attachment

Title	*Purpose and revision cycle (incl. links)*
CGMS Baseline	(This document) Revised at least every 4 years
CGMS Contingency Plan	Defines guidance and the process for identifying, mitigating, and coping with risks to the continuity of the CGMS Baseline. https://www.cgms-info.org/documents/CGMS_contingency_plan_Aug2019.pdf (Ref. CGMS-46-CGMS-WP-28)
CGMS High-Level Priority Plan (HLPP)	4-year rolling plan containing high-level priorities for CGMS activities. Aspirational targets for enhancing the CGMS response to the WIGOS Vision are included in the HLPP. Revised annually. https://www.cgms-info.org/documents/CGMS_HIGH_LEVEL_PRIORITY_PLAN.pdf
WMO Gap Analysis	Contains the WMO gap analysis of CGMS Baseline against the WIGOS Vision. Document provided to CGMS at least every 4 years. CGMS-49-WMO-WP-13
WIGOS Vision	Contains the overall vision for the complete observing system, based on WMO requirements. See WMO-No. 1243 and https://community.wmo.int/vision2040

1.3 Scope of the Baseline

The Baseline enumerates the observations and their supporting missions that provide meteorological and environmental data required to support the WMO application areas. Support of this goal requires coordination and cooperation among all CGMS members. In order to ensure efficient allocation of resources and timely cooperation, the capabilities contained herein are considered the aggregate baseline capabilities of all CGMS members.

In the development of the scope of the Baseline, the following principles determined which missions were included:

- σ Commitment by CGMS members to provide a capability;
- σ Long-term sustained provision of the capability by CGMS members;
- σ Data from missions are available on a free and unrestricted basis;
- σ Data can be utilized in operational applications.

This document takes a holistic approach and therefore includes space-based observations; services, including data collection and direct broadcast; as well as data sharing and distribution.

1.4 Evolution of the Baseline

The Baseline will be updated at least every four years to take into account the evolving programmatic plans of CGMS members and the WMO Gap Analysis of the CGMS Baseline against the WIGOS Vision. The process for updating the CGMS Baseline is illustrated in Figure 1 below.

Following approval of the CGMS Baseline, WMO will include the revised CGMS Baseline in the new Manual on WIGOS.

1.5 Additional response to the WIGOS Vision

The Baseline constitutes the most comprehensive CGMS response to the WIGOS Vision possible under the current programmatic constraints and specific national priorities. CGMS will continue to strive for a full implementation of the WIGOS Vision and CGMS Working Group III will propose targets for extending the response to the WIGOS Vision. These targets will (after approval by the CGMS plenary) be reflected in the 4-year rolling CGMS High-Level Priority Plan, and will be reflected in the CGMS Baseline when realised as fully committed contributions by CGMS members.

2. OBSERVATIONS AND ORBITS

The orbits considered by CGMS for exploitation include Low Earth Orbit (LEO), Geostationary Orbit (GEO), Highly Elliptical Orbit (HEO), and at the L1 Lagrange point.

- σ LEO may be sun-synchronous or drifting. Sun-synchronous orbits may have Equatorial Crossing Time (ECT) in the “early morning” (typically, 5:30 and 17:30), the “mid-morning” (typically, 9:30 and 21:30) or the “afternoon” (typically, 13:30 and 1:30). They overfly approximately the same location of the Earth, including high latitudes, at approximately the same time twice/day. For large-swath instruments, coverage at 4-hour intervals requires three satellites at fairly spaced ECT’s. Drifting orbits with different inclination provide more frequent coverage of lower latitudes and ensure the viewing of the Earth at changing times of the diurnal cycle.

- σ GEO provides continuous view of about one third of the Earth's surface centred on the stationary sub-point. Full coverage of all longitudes, excluding polar regions, requires a number of evenly spaced satellites.

- σ HEO can be used for frequent Earth observation of high latitudes, or to fly through the magnetosphere at various distances from the Earth, for the purpose of space weather. [Note that HEO missions are being planned by some CGMS members but are not yet considered part of the CGMS Baseline].

- σ L1 provides continuous view of the Sun, and in situ detection of particles of the solar wind several minutes before they reach the magnetosphere and the Earth.

- σ The term Sun-Earth line used below should be understood as covering observations that may be obtained from any suitable orbital position on the line connecting the Sun and the Earth when monitoring or observing the sun. Typical orbital positions include GEO and the first Lagrangian Point (L1). Requirement for continuous observations needs to be taken into account for orbits around the Earth because of potential satellite eclipses.

- σ Other orbits away from the Sun-Earth line (such as L5 or L4) can be used for solar and heliospheric imaging and in situ measurements for space weather to improve the coverage and enhance space weather forecasting.

The observations are a combination of active and passive remotely sensed observations, and in situ measurements.

Table 2. Overview of orbits and observations currently considered by CGMS

Sensor type	*Orbit*	*Observations*	*Attributes*
Microwave sounder	LEO	Atmospheric temperature, humidity, and precipitation	3 sun-synchronous orbits, nominally early morning, mid-morning and afternoon
Hyperspectral infrared sounder	LEO, GEO	Atmospheric temperature, humidity, and winds. Atmospheric composition: CO, CO_2, SO_2, depending on spectral band also CH_4 and NH_3	LEO – 3 sun-synchronous orbits, nominally early morning, mid-morning and afternoon GEO – 2 slots: 86.5°–105°E range and 0°
Radio occultation	LEO	Atmospheric temperature and humidity, ionospheric electron density	Minimum 6 000 occultations from low inclination orbits (<30°) distributed geographically and temporally in local time, 1 000 occultation from other drifting orbits, and 7 600 occultations from sun-synchronous orbits. Electron density profiles up to 500 km.

Sensor type	*Orbit*	*Observations*	*Attributes*
Multi-purpose meteorological imagers (multispectral, visible, and IR)	LEO, GEO	Sea-surface temperature (SST), aerosols, land-surface temperature, cloud properties, feature tracking winds (AMV), flood mapping, fires, cryosphere applications (sea ice, snow cover, etc.), ocean colour	LEO – 3 sun-synchronous orbits, nominally early morning, mid-morning, and afternoon IR dual-angle view imagery for high-accuracy SST (at least one a.m. spacecraft) GEO – 137°W, 75.2°W, 0°, 74°E, 76°E, 82°E, 86.5°E-105°E, 128.2°E, 140°E
Multi-viewing, multi-channel, multi-polarization imager	LEO	Aerosol, cloud microphysics, BRDF (Bidirectional Reflectance Distribution Function)	LEO – 1 sun-synchronous orbit
Lightning mapper	GEO	Lightning mapping	GEO – 137°W, 75.2°W, 0°, 86.5°E-105°E
Broadband short/long wave radiometer	LEO	Radiation balance	LEO – 2 sun-synchronous orbits, early morning and afternoon orbit
Visible/UV spectrometer	LEO, GEO	Aerosol, Atmospheric composition: O_3, CO_2, NO_2, SO_2, BrO, Cl	LEO – 2 sun-synchronous orbits mid-morning and afternoon GEO – 2 slots at 0° and 128.2°E
UV limb spectrometer	LEO	Aerosol, Atmospheric composition: O_3	LEO – 2 sun-synchronous orbits, mid-morning, afternoon
SWIR imaging spectrometer	LEO	Atmospheric composition: CO_2, CH_4	LEO – 2 orbit sun-synchronous late morning or afternoon
Precipitation radar	LEO	Precipitation	LEO – drifting orbit
Microwave imager	LEO	Sea-surface temperature, ocean surface winds, precipitable water, soil moisture, snow and ice properties, sea-ice properties, precipitation, cloud liquid water	LEO – 2 sun-synchronous orbits, nominally mid-morning and afternoon
Narrow band imager	LEO, GEO	Ocean colour, aerosol	LEO – 2 orbits GEO – 1 slot, 128.2°E
Radar altimetry	LEO	Ocean surface topography	LEO – 1 orbit mid-morning as well as reference mission on a high-precision, drifting orbit
Scatterometer	LEO	Ocean surface winds	LEO – 3 sun-synchronous orbits, early morning, mid-morning and afternoon orbits
Submillimetre ice cloud imager	LEO	Cloud ice	LEO – sun synchronous mid-morning orbit
Synthetic aperture radar	LEO	Soil moisture, sea ice	LEO – 1 orbit
High resolution optical imager	LEO	Land use, vegetation type and status, aerosol	LEO – 1 orbit
Coronagraph	Sun-Earth line	Coronagraphy	GEO – 1 slot L1

Sensor type	*Orbit*	*Observations*	*Attributes*
EUV imager	Sun-Earth line	EUV imagery	GEO – 2 slots LEO – 1 orbit
X-Ray spectrograph	Sun-Earth line	X-Ray flux	GEO – 2 slots L1
Energetic particle sensor	LEO, GEO, L1	Magnetospheric and solar energetic particles	LEO – 3 orbits GEO – 137°W, 75.2°W, 0°, 31°E, 86.5°E-105°E, 128.2°E including hosted payload missions L1 as in situ measurement
Magnetometer	GEO, L1	Earth's magnetic field, interplanetary magnetic field	GEO – 4 slots: 137°W, 75.2°W, 86.5°E-105°E, 128.2°E, in situ measurement L1 as in situ measurement
Plasma Analyser	L1	Solar wind	L1 as in situ measurement

3. SERVICES

3.1 Data sharing services

Meteorological applications in general are critically dependant on global exchange of observation data. The international exchange of satellite data obtained by the CGMS Baseline system is a vital element of the WMO Integrated Global Observing System, which underpins the operational weather, climate, hydrological and other environmental services of all 193 WMO Members. In particular, it provides critical global input data for the WMO Members designated as Global Producing Centres for long- and medium-range weather forecasts, Tropical Cyclone Forecasting Centres and Centres for Transport Modelling for Environmental Emergency Response. CGMS members will establish and operate terrestrial and space-based dissemination services in order to exchange observations directly among members, and to make them available to National Hydrological and Meteorological Services and to the broader international user community in a timely and cost-effective manner. This data exchange should follow CGMS best practices.

3.1.1 *Direct broadcast services*

The core meteorological satellite systems in LEO orbits, and other operational satellite systems where applicable, should ensure low latency data access of imagery, sounding, and other real-time data of interest to users by means of direct broadcast or other mechanisms. Application areas where low latency and availability is suitable include Severe Weather Monitoring, Nowcasting and Short- and Medium-Range Numerical Weather Prediction. Other application areas could also benefit from very low latency products, such as ionospheric monitoring. CGMS members should follow the best practices for direct broadcast services developed by CGMS Working Group I.

3.2 In situ data relay

CGMS members will provide for the relay of in situ meteorological and environmental information from fixed and mobile platforms (such as ocean buoys, tide gauges, tsunami platforms, and river gauges). In situ data relay services should be provided on both LEO and GEO satellites when relevant.

4. ENSURING DATA AND SERVICES

To ensure quality and continuity of observations CGMS members will take the following steps in the provision of their data and services.

4.1 Calibration and validation

CGMS members are responsible for ensuring the quality and compatibility of satellite observations taken at different times and locations, by different instruments, and by various satellite operators. CGMS members will characterize instruments prior to launch, follow the common methodologies, and implement operational procedures outlined by Global Space-based Inter-Calibration System (GSICS). Instruments should be inter-calibrated on a routine basis against reference instruments or calibration sites.

CGMS will strive to achieve global compatibility of satellite products, by establishing commonality in the derivation of satellite products for global users where appropriate and by fostering product validation and inter-satellite comparison through International Science (SCOPE)-type mechanisms.

4.2 Contingency planning to ensure continuity

CGMS members will take steps to ensure continuity of this CGMS Baseline by following the guidelines outlined in the CGMS contingency plan.

4.3 Monitoring implementation of the Baseline

CGMS will monitor members' implementation of the CGMS Baseline through an annual risk assessment. CGMS members will provide the information necessary to compare current observing capabilities against the CGMS Baseline. This assessment is outlined in the CGMS global contingency plan.

4.4 Research to operations and employing research missions

The CGMS Baseline focuses on satellite missions that are provided on an operational and sustained basis. This does not preclude the use by CGMS members of other missions undertaken on a research or experimental basis (for example, to demonstrate a specific capability). Research and experimental missions support the CGMS Baseline by:

- Supplementing the CGMS Baseline observations.
- Providing a pathway for new sensors and observations to be added to the CGMS Baseline as future operational missions.
- Supporting contingency operations in the case of a gap in the CGMS Baseline.

4.5 System compatibility and interoperability

In order to help maintain a robust WMO Global Observing System (GOS), CGMS members shall work through CGMS Working Groups I, II and IV to establish and adopt best practices for interoperability and compatibility of systems and services.

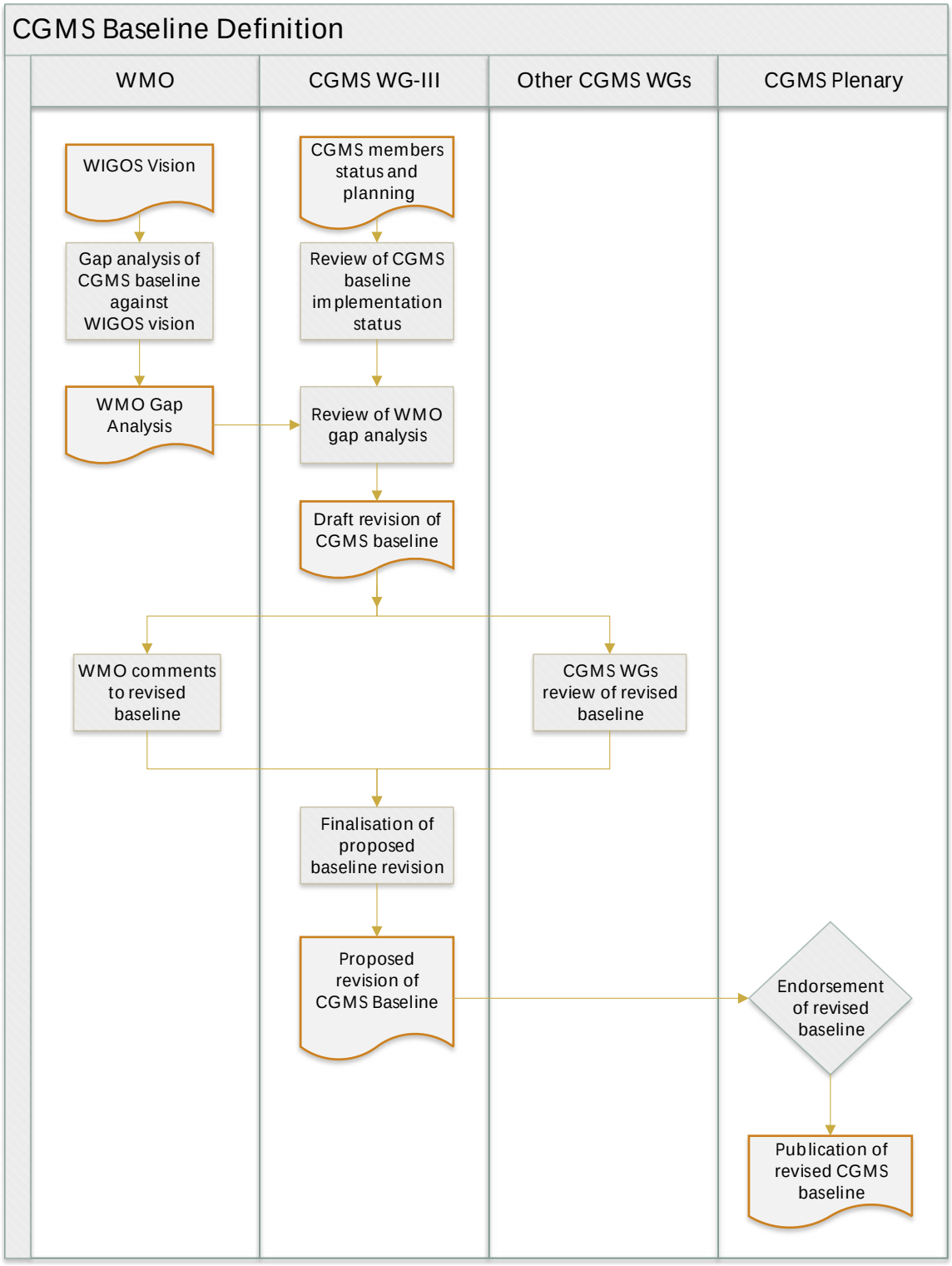
CGMS Baseline Definition
WMO
CGMS WG-III
Other CGMS WGs
CGMS Plenary
WIGOS Vision
CGMS members status and planning
Gap analysis of CGMS baseline against WIGOS vision
Review of CGMS baseline implementation status
WMO Gap Analysis
Review of WMO gap analysis
Draft revision of CGMS baseline
WMO comments to revised baseline
CGMS WGs review of revised baseline
Finalisation of proposed baseline revision
Proposed revision of CGMS Baseline
Endorsement of revised baseline
Publication of revised CGMS baseline

Figure 1. CGMS baseline process

5. ATTRIBUTES SPECIFIC TO THE GLOBAL OBSERVING SYSTEM OF THE WORLD WEATHER WATCH

Notes:
1. The provisions of sections 1, 2, 3 and 4 are common to all WIGOS component observing systems including GOS. This section contains additional provisions for standard and recommended practices and procedures related to surface-based observations for GOS.
2. The implementation of GOS encompasses the use of surface- and space-based meteorological (weather and climate) observations, but does not include hydrological or cryospheric observations or those related to the chemical composition and related physical characteristics of the atmosphere.

5.1 REQUIREMENTS

5.1.1 Members shall ensure that time and frequency of observations meet user observational requirements for timeliness and temporal resolution.

Note: These requirements are specified in the OSCAR/Requirements database (http://www.wmo-sat.info/oscar/observingrequirements) with further details provided in other sections of this Manual.

5.1.2 Members should make and provide real-time observations in areas where special weather phenomena are occurring or are expected to develop.

Note: Specific requirements may arise in special circumstances as described in 2.2.2.3.

5.2 DESIGN, PLANNING AND EVOLUTION

5.2.1 Composition of the Global Observing System of the World Weather Watch

5.2.1.1 Members shall design and plan the meteorological component of their surface-based observing network so as to address the requirements of the WMO application areas associated with the World Weather Watch.

Note: The breadth of activities associated with the World Weather Watch includes climatology, agricultural meteorology, aeronautical meteorology and other WMO application areas, and is increasing over time as meteorological science and operations evolve.

5.2.1.2 Members shall provide surface-based meteorological observations from one or more of the following types of station/platform:

(a) Surface land stations (see Appendix 5.1);

(b) Surface marine stations (see Appendix 5.2);

(c) Upper-air stations (see Appendix 5.3);

(d) Aircraft meteorological stations (see Appendix 5.4);

(e) Radar wind profiler stations (see Appendix 5.5);

(f) Weather radar stations (Appendix 5.6).

Notes:
1. Any station may belong to more than one of the above categories (a) to (f).
2. A coastal station makes both surface land and surface marine observations. Hence, it may be considered as belonging to both categories (a) and (b).

5.2.1.3 When operating these types of station, Members shall follow the provisions defined in the appendices to this section.

5.2.1.4 For stations contributing to GCOS networks, Members shall follow the provisions defined in Appendix 5.7.

Note: Stations identified as contributing to GCOS networks are selected from categories (a) to (f) under 5.2.1.2. It is necessary for Members to check which of their stations have been selected for inclusion in GCOS networks. This information may be found on the GCOS web site at https://gcos.wmo.int/en/networks.

5.2.2 Principles for observing network design and planning

Members shall take into account global and regional observational requirements when they establish their national observing network.

5.3 INSTRUMENTATION AND METHODS OF OBSERVATION

5.3.1 Members shall reduce the observed atmospheric pressure at a station to mean sea level, except at those stations specified in the *Manual on Codes* (WMO-No. 306), Volume II, section A.1, 12.1, for each Region (Chapter I – VI) and the Antarctic (Chapter VII).

Note: Detailed guidance on the measurement of atmospheric pressure is given in the *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume I, Chapter 3, 3.7.

5.3.2 Members shall ensure that instruments for air temperature and humidity measurements are mounted in such a way that the sensors are at the same height, within 1.25 and 2.0 m above ground.

Notes:
1. Detailed guidance is provided by the *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume I, Chapters 2 and 4.
2. When considerable snow cover occurs, a greater height is permissible in order to maintain the correct height above the snow surface.

5.3.3 Members shall ensure that the exposure of wind instruments over level, open terrain is 10 m above ground.

Notes:
1. Detailed guidance is available in the *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume I, Chapter 5, 5.9.
2. At an aeronautical meteorological station, Members should install the wind instruments in accordance with the *Technical Regulations* (WMO-No. 49), Volume II, Part II, 4.1.1.

5.3.4 Members shall ensure that the averaging period for surface wind observations is ten minutes, except that when the 10-minute period includes a marked discontinuity in the wind direction and/or speed, only observations/ measured data after the discontinuity is used for obtaining mean values.

Notes:
1. A marked discontinuity is defined in the *Manual on Codes* (WMO-No. 306), Volume I.1, 15.5.1 (for aerodrome meteorological observation).
2. In such a case, the time interval is correspondingly reduced.

3. Detailed guidance is provided in the *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume I, Chapter 5, and Volume V, Chapter 2.
4. For wind observations at an aeronautical meteorological station, Members should follow the *Technical Regulations* (WMO-No. 49), Volume II, Part I, 4.1 and 4.6.1, and Part II, Appendix 3, 4.1.3.

5.3.5 Member should indicate "calm" when the average wind speed is less than 0.5 m s^{-1}.

Note: In that case, the wind direction is reported as 0.

5.3.6 **For all cloud observations, Members shall use the tables of classification, definitions and descriptions of clouds as given in the *International Cloud Atlas: Manual on the Observation of Clouds and Other Meteors* (WMO-No. 407).**

Note: See the *Guide to Instruments and Methods of Observation (WMO-No. 8)*, Volume I, Chapter 15, for further details.

5.3.7 **Members shall comply with the *International Cloud Atlas: Manual on the Observation of Clouds and Other Meteors* (WMO-No. 407) when observing and reporting present and past weather.**

Note: See the *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume I, Chapter 14, 14.2, for further details.

APPENDIX 5.1. ATTRIBUTES SPECIFIC TO SURFACE LAND METEOROLOGICAL STATIONS

Note: Guidance on the operation of surface land networks is provided in the *Guide to the Global Observing System* (WMO-No. 488), Part III, 3.2; the *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume III, Chapters 1 and 2; the *Guide to Climatological Practices* (WMO-No. 100), Chapter 2; and *Global Observing System for Climate: Implementation Needs*, GCOS-200.

5.1.1 **Members shall ensure that each station is located so as to provide observations representative of the area in which it is situated.**

Note: The size of this area may be different for different applications.

5.1.2 **Members shall ensure that the actual time of observation is as close as possible to the reported time of observation.**

Notes:
1. In general, the measurement of atmospheric pressure is the most sensitive to the time of observation and is to be made at the reported time. Observations of other variables are made over the 10-minute period immediately preceding the reported time.
2. Automated systems can generally match the actual time with the reported time, however, manual observations occur over a period of time, especially when many variables are to be observed.
3. It is desirable to report the time of observation for each observed variable where possible and when accommodated by the reporting code.

5.1.3 **Members making synoptic observations at their surface land stations shall observe the meteorological variables listed in Attachment 5.1.**

Note: The list shows differences between manual and automatic stations, as well as some variables to be included whenever possible or specified as a regional requirement.

5.1.4 **Members making synoptic observations shall do so at least at the main standard times.**

5.1.5 Members making synoptic observations should do so at the intermediate standard times and the additional standard times.

Note: The three-hour frequency of the intermediate standard times provides value for several application areas, while an hourly frequency of the additional standard times provides further value for many application areas.

5.1.6 Members who include snow depth observations as part of their synoptic observations should do so at least at the main standard times.

5.1.7 **Members who include snow depth observations as part of their synoptic observations shall do so at least once per day.**

Notes:
1. In this case, the time of the snow depth observations is to be the same each day.
2. When snow is not present, snow depth is to be reported as zero (0 cm) for the entire period during which snow is expected but is not present, as determined by resolutions of regional associations.

Observations for climate applications

5.1.8 Each Member shall establish and maintain at least one reference climatological station.

5.1.9 Members should ensure that each reference climatological station maintains the specified exposure with long-term stability.

Notes:
1. Exposure requirements are specified in the *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume I, 1.1.2, 1.3.3, 1.3.4, and in the *Guide to Climatological Practices* (WMO-No. 100), 2.4.
2. Good exposure allows observations to be made in representative conditions, and long-term stability will support the homogeneity of the series of observations.

5.1.10 Members shall make climate observations at a sufficient number of their surface land stations to address the requirements of climate applications.

5.1.11 Members making climate observations for climate applications shall observe the Essential Climate Variables as specified in Appendix 5.8.

5.1.12 Members making observations for climate applications should ensure that observations are made at fixed times, according to either UTC or Local Mean Time, which remain unchanged throughout the year.

Note: When changing to daylight saving time, also known as summer time, observations shall be made one hour later on the local clock.

5.1.13 Members making observations for climate applications two or more times per day should select times that reflect the significant diurnal variations.

5.1.14 Members should provide monthly summaries of observations made at their surface land stations.

Notes:
1. See section 3.2.2 (under development).
2. Monthly summaries have long been provided as CLIMAT messages, offering a valuable basic set of climatological information.
3. The *Handbook on CLIMAT and CLIMAT TEMP Reporting* (WMO/TD-No. 1188) provides instructions on how to set up reports and bulletins in the CLIMAT (TEMP) (SHIP) codes.
4. CLIMAT reports are to be transmitted by the fifth day of the month (and no later than the eighth day of the month).
5. CLIMAT reports require quality control not only of the measurements themselves, but also of their message encoding to ensure their accurate transmission to national, regional and world centres. Quality checks should be made on site and at a central facility designed to detect equipment faults at the earliest stage possible.

Observations for aeronautical meteorology

5.1.15 Members should make observations for aeronautical meteorology at a sufficient number of their surface land stations to address the requirements of aeronautical meteorology.

5.1.16 Members making observations for aeronautical meteorology shall observe the meteorological variables listed in Attachment 5.1.

Note: In addition to the provisions concerning observations for aeronautical meteorology laid out in this Manual, see the relevant ICAO provisions in the *Technical Regulations* (WMO-No. 49), Volume II, Part I, 4 and 5.

Observations for agricultural meteorology

5.1.17 Members should make observations for agricultural meteorology at a sufficient number of their surface land stations to address the requirements of agricultural meteorology.

5.1.18 Members should locate those stations that support agricultural meteorology at a place that is representative of agricultural and natural conditions in the area concerned.

Note: To comply with their obligations to collect and share metadata regarding stations that support agricultural meteorology, Members can refer to the *WIGOS Metadata Standard* (WMO-No. 1192), Chapter 7, Code Table 4-01, which includes natural biomass, main agrosystems and crops of the area, types of soil, physical constants and profile of soil.

5.1.19 **Members making observations for agricultural meteorology shall observe the meteorological variables listed in Attachment 5.1.**

Note: Detailed guidance on observing practices of agricultural meteorological observing systems and instruments is given in the Guide to Instruments and Methods of Observation (WMO-No. 8), Volume I, Chapters 1, 2, 5, 7, 10 and 11; and Volume III, Chapter 9, and in the *Guide to Agricultural Meteorological Practices* (WMO-No. 134), Chapter 2.

Lightning location observations

5.1.20 Members should consider acquiring observations from lightning location systems.

Notes:
1. A detailed description of methods in use is provided in the *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume III, Chapter 6.
2. A surface-based sensor at a single station can detect the occurrence of lightning but cannot be used to locate it on an individual flash basis. A network of stations is needed for accurate lightning location.

5.1.21 Members should ensure that the spacing and number of stations is consistent with the technique used and the desired coverage, detection efficiency and accuracy of location.

Radiation observations

Note: Detailed guidance about radiation observations is given in the *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume I, Chapter 7; guidance on operations is available in the *Guide to the Global Observing System* (WMO-No. 488), Part III, 3.9.2.2.

5.1.22 Members should establish at least one principal radiation station in each climatic zone of their territory.

Note: The historical concept of principal and ordinary radiation stations will be replaced in a future edition of this Manual by updated terminology including provisions relating to the Baseline Surface Radiation Network (BSRN).

5.1.23 Members should make radiation observations with spacing not exceeding 100 km.

Note: The user observational requirements for radiation climatology and other applications are specified in the OSCAR/Requirements database (see http://www.wmo-sat.info/oscar/observingrequirements). Spacing exceeding 100 km would not satisfy the threshold requirement of any application area.

5.1.24 **Members shall make available the metadata of their radiation stations in accordance with the provisions of section 2.5.**

Note: Metadata of radiation stations should include the category of the station, details of radiometers in use (type and serial number of each instrument, calibration factors, dates of any significant changes), the exposure of radiometers, including height above ground, details of the horizon of each instrument, and the nature of the surface of the ground.

5.1.25 **When commencing radiation observations, Members shall ensure adequate exposure that will not change over time.**

5.1.26 Radiation observations should include at least the following:

(a) Continuous recording of global radiation at the Earth's surface;

(b) Recording of sunshine duration.

5.1.27 At principal radiation stations, the observing programme should include:

(a) Continuous recording of global radiation at the Earth's surface and its direct and diffuse components;

(b) Recording of sunshine duration;

(c) Regular measurements of net radiation (radiation balance) over natural and crop soil cover (made over a 24-hour period).

5.1.28 **Members shall express radiometric measurements in accordance with the World Radiometric Reference.**

Notes:
1. The *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume I, Chapter 7, 7.1.2.2, and Annex 7.A, provides further details on radiometric measurements.
2. In the near future, an SI standard will be available.

5.1.29 Members who make direct solar radiation observations without continuous recording should do so at least three times per day.

Note: In such circumstances, measurements require that the sun and the sky in the vicinity are free from cloud, and that three observation times provide three different solar heights, one of them being near the maximum.

5.1.30 Members who make long-wave radiation observations without continuous recording should do so every night, at least once soon after the end of the evening civil twilight.

APPENDIX 5.2. ATTRIBUTES SPECIFIC TO SURFACE MARINE STATIONS

Note: Guidance on the operations of surface marine networks is provided in the *Guide to the Global Observing System* (WMO-No. 488), Part III, 3.2 and 3.6, and in the *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume III, Chapter 4. Other relevant guidance may be found in the *Guide to Marine Meteorological Services* (WMO-No. 471).

5.2.1 Members should make surface marine observations with spatial density in all marine areas which meets the requirements of WMO application areas.

Notes:
1. Members can achieve this by establishing surface marine stations, both fixed and mobile, in their territorial and international waters.
2. Where possible, Members can also consider the opportunity to make subsurface observations from their surface meteorological stations, for example, from ships.

5.2.2 **Members making surface marine observations shall ensure that metadata are updated in accordance with the provisions of 2.5 and are available to the database of the WMO-IOC Joint Centre for Oceanography and Marine Meteorology in situ Observations Programmes Support (OceanOPS).**

Notes:
1. The OceanOPS database provides an interface to the WIGOS Information Resource – OSCAR/Surface.
2. In the case of ship observations, relevant metadata include also the name, call sign and route or route designator of each ship.

5.2.3 Members making surface marine observations should establish as many sea stations as possible in data-sparse areas and areas of particular interest for WMO application areas.

Note: This may be achieved by recruiting ships and deploying drifting buoys in such areas, and by giving consideration to fixed or moored platforms wherever possible.

5.2.4 Members operating stations on fixed structures and/or moored buoys should ensure that their location provides observations representative of the area in which stations are situated.

5.2.5 **Members making surface marine observations shall include as many meteorological variables as possible among those listed in Attachment 5.1.**

5.2.6 **Members making surface marine observations shall do so at least at the main standard times.**

5.2.7 Members making surface marine observations should do so at the intermediate standard times and the additional standard times.

Note: Achieving the three-hour frequency of the intermediate standard times provides value for several application areas, while achieving an hourly frequency of the additional standard times provides further value for many application areas.

5.2.8 When operational difficulties on board ship make a surface marine observation impracticable at a main standard time, the actual time of observation should be as near as possible to the main standard time.

5.2.9 Whenever storm conditions threaten or prevail, or other sudden and dangerous weather and marine developments are encountered, surface marine observations should be made and reported as soon as possible and more frequently than at the main standard times.

Notes:
1. Storm conditions refer to the Beaufort scale number 10 and higher.

2. Some observing stations/platforms are better than others for making such ad-hoc observations.

5.2.10 **Members shall report and make available surface marine observations in real time.**

Note: Logistics of communications from remote areas may prevent this in certain circumstances.

5.2.11 Members should report and make available surface marine observations also in non-real-time through the Marine Climate Data System, appropriate Data Acquisition Centres and Global Data Assembly Centres.

Notes:
1. The Marine Climate Data System (MCDS) aims to standardize the data system and facilitate access to observations for climate studies and monitoring in accordance with the GCOS climate monitoring principles (Appendix 2.2) and is defined in the *Manual on Marine Meteorological Services* (WMO-No. 558), Volume I, Part VII.

2. Further guidance and information on the structure and different centres within the MCDS can be found in the *Guide to Marine Meteorological Services* (WMO-No. 471), Section 9.3.

Sea-level observations

5.2.12 Members should establish a network of sea-level observing stations along their coasts.

Notes:
1. The design of such networks will consider the requirements of WMO and their partners, and will address topics including storm surges, tsunamis, tidal observations and predictions, and climate trends.
2. Guidance can be found in the *Manual on Sea-level Measurement and Interpretation*, IOC Manuals and Guides No. 14, Volume IV, (WMO/TD-No. 1339; JCOMM Technical Report No. 31), and the *Manual on Sea-level Measurements and Interpretation*, IOC Manuals and Guides No. 14, Volume V: Radar Gauges (JCOMM Technical Report No. 89).

5.2.13 Members should make sea-level observations at the main standard times and, in extreme circumstances, as soon as possible and more frequently.

Note: Extreme circumstances may include tsunamis and storm surges.

Research and special-purpose vessel stations

5.2.14 Members operating research and special-purpose vessels should ensure that all such vessels are recruited to be WIGOS stations/platforms.

Note: Such vessels may provide valuable observations and are to be encouraged to provide as many meteorological surface and upper-air observations as possible, and subsurface observations down to the thermocline and below, in accordance with the procedures agreed between WMO and the Intergovernmental Oceanographic Commission of the United Nations Educational, Scientific and Cultural Organization.

APPENDIX 5.3. ATTRIBUTES SPECIFIC TO UPPER-AIR STATIONS

Note: Guidance is provided in the *Guide to the Global Observing System* (WMO-No. 488), Part III, 3.3, and in the *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume I, Chapters 12 and 13.

5.3.1 Members should establish a network of upper-air stations/platforms.

5.3.2 Members making upper-air observations should observe as many as possible of the meteorological variables listed in in Attachment 5.1.

5.3.3 Members should make upper-air synoptic observations from at least some of their upper-air stations.

Note: Collections of standard sets of variables at standard times have long been referred to as synoptic observations. Upper-air synoptic observations have in the past been made by radiosonde systems and other balloon-borne systems. Upper-air networks now also make extensive use of other systems.

5.3.4 **An upper-air synoptic observation shall include a vertical profile of one or more of the following variables:**

(a) Wind direction and speed;

(b) Air temperature;

(c) Humidity;

(d) Atmospheric pressure.

Notes:
1. In general, profiles with a high vertical resolution provide greater value for users. Requirements for vertical resolution are documented in the OSCAR/Requirements database and are described separately for the lower troposphere, high troposphere and lower stratosphere.
2. In general, profiles of all the above variables provide greater value than profiles of a single variable. In particular, radiosonde profiles are highly valued.
3. In the tropics, priority is to be given to upper-air wind profile observations.
4. While atmospheric pressure has, in the past, been used as an altitude coordinate, it may also be useful for non-hydrostatic applications.

5.3.5 **An upper-air synoptic observation shall include the altitude of each observation in the profile.**

Note: Different technologies use different methods to determine altitude. Modern Global Navigation Satellite Systems enable an accurate determination of altitude; however, it remains desirable for radiosondes to also report atmospheric pressure.

5.3.6 An upper-air synoptic observation should include accurate time and horizontal location of each observation in the profile.

5.3.7 Upper-air synoptic observations should be made and reported at the main standard times.

5.3.8 **Upper-air synoptic observations shall be made and reported at least at 0000 and 1200 UTC.**

5.3.9 For Members using balloon-tracking systems, the balloon release time should be such that the nominal time of the profile observation is near the midpoint of the flight.

Note: Although a balloon flight extends over a period generally exceeding one hour, the resulting profile observation is characterized by a name such as "0000 UTC flight" or "1200 UTC flight". This is the nominal time of the profile observation, however, the balloon release time will be 30 to 45 minutes before the nominal time, or even longer if the balloon is expected to continue ascending to greater heights.

5.3.10 Members should consider equipping suitable ships to provide upper-air synoptic observations.

Other remote-sensing profiler stations

5.3.11 Members should consider the establishment of other remote-sensing profilers.

Note: In addition to the radar wind profiler, addressed in Appendix 5.5, a range of other remote-sensing technologies is being used to collect wind and thermal profiles of the atmosphere. The *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume III, Chapter 5, 5.2, provides further information about acoustic sounders (sodars), radio-acoustic sounding systems, microwave radiometers, laser radars (lidars) and the global navigation satellite system. Doppler weather radars may also be used to derive wind profiles.

Planetary boundary-layer observations

5.3.12 Members should establish stations for making observations in the planetary boundary layer.

Notes:

1. These observations are profiles of air temperature, humidity, atmospheric pressure and wind in the lowest 1 500 m of the atmosphere.
2. This information is required in the study of diffusion of atmospheric pollution, the transmission of electromagnetic signals, the relation between free-air variables and boundary-layer variables, severe storms, cloud physics, convective dynamics, and the like.
3. Some of the vertical and horizontal sounding systems that could be applied to specific problems for limited periods in a variety of locations are described in the *Guide to the Global Observing System* (WMO-No. 488), Part III, 3.9.2.7, and in the *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume III, Chapter 5.

APPENDIX 5.4. ATTRIBUTES SPECIFIC TO AIRCRAFT METEOROLOGICAL STATIONS

Notes:

1. In addition to the provisions for aircraft-based observations laid out in this Manual, see the relevant ICAO provisions for observations from aircraft in *Technical Regulations* (WMO-No. 49), Volume II, Part I, 5.
2. Guidance on the operations of aircraft meteorological stations is provided in the *Guide to the Global Observing System* (WMO-No. 488), Part III, 3.4, and in the *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume III, Chapter 3.
3. Guidance on the development and operation of the Aircraft Meteorological Data Relay (AMDAR) programme is provided in the *Guide to Aircraft-based Observations* (WMO-No. 1200).
4. More details and further requirements concerning measurement and data processing are available in the *AMDAR Onboard Software Functional Requirements Specification* (Instruments and Observing Methods, Report No. 115, Chapter 3). This publication also provides the standard for the meteorological functionality of AMDAR software applications and air-ground data formats.
5. Some relevant specifications and guidance can be found in the ARINC *620-8 Data Link Ground System Standard and Interface Specification* (DGSS/IS), which provides specifications of the meteorological report.

5.4.1 Members should arrange for meteorological observations to be made by aircraft of their registry operating on national air routes, and for the recording and reporting of these observations.

Note: These aircraft-based observations can make a significant contribution to the requirements of WMO application areas, particularly if they are made day and night with adequate distribution in space and time.

5.4.2 Members should collaborate with their civil aviation authorities regarding compliance with ICAO requirements for the provision of aircraft reports in support of international air navigation.

Note: Such requirements include the forwarding of aircraft reports by civil aviation authorities to ICAO World Area Forecast Centres (WAFCs) on the aviation telecommunications network so that they can subsequently be made available to WMO Members on the WMO Information System (WIS).

5.4.3 Members should participate in the WMO AMDAR observing system.

5.4.4 **Members operating AMDAR observing systems shall provide measurement of air temperature, wind speed, wind direction, pressure altitude, latitude, longitude and time of observation.**

5.4.5 Members who operate AMDAR observing systems should include measurement of humidity or water vapour, turbulence, icing and geometric altitude as additional components of AMDAR observations.

Notes:

1. Turbulence: mean, peak and event-based Eddy Dissipation Rate (EDR) – desirable
2. Turbulence: derived equivalent vertical gust (DEVG) – optional

5.4.6 **Members making aircraft-based observations available to the WIS shall have the authorization to do so from the observational data owner.**

Notes:

1. The *Guide to Aircraft-based Observations* (WMO-No. 1200), Appendices A and B, provides detailed information on quality control and monitoring of aircraft-based observations.
2. The WMO lead centre on aircraft data undertakes quality monitoring of aircraft-based observations and makes monitoring information available to members at https://community.wmo.int/activity-areas/aircraft-based-observations/data/monitoring.

5.4.7 Members operating AMDAR observing systems shall ensure that on-board data quality control is applied in accordance with WMO specifications.

Note: The *Guide to Aircraft-based Observations* (WMO-No. 1200), 1.8 and Appendix A, provides further details.

5.4.8 Members who receive and process aircraft-based observations from any source, including AMDAR and other aircraft-based observing systems, shall make such data available through the WIS in accordance with WMO specifications.

Note: Members need to be aware of specific requirements for handling ICAO-related observations, which are explained in the *Guide to Aircraft-based Observations* (WMO-No. 1200). Guidance on the encoding and provision of aircraft-based observations to the WIS can also be found there.

5.4.9 Members who receive, process and make available to the WIS aircraft-based observations from any source shall record, retain and make available observational metadata in accordance with the provisions of section 2.5.

Note: The *Guide to Aircraft-based Observations* (WMO-No. 1200), section 1.10 and Appendix D, provides further details. Relevant metadata include those relating to the following aspects and elements of the observational data:

(a) Models and types of aircraft;
(b) When and where possible, on-board sensors and their siting, calibration and operational issues and faults;
(c) Specific software and algorithms used to process data to generate the reported variables;
(d) Metadata related to quality control processes, data communication practices, data processing and delivering centres.

5.4.10 Members should report disruptions in the normal quality or availability of observations to the relevant WMO global or regional Aircraft Based Observation (ABO) lead centre and to WMO Focal Points on Aircraft-based Observations.

Note: The *Guide to Aircraft-based Observations* (WMO-No. 1200) provides further details. See also 2.4.5 of this Manual.

5.4.11 Members making aircraft-based observations internationally available shall develop procedures for the detection, communication and timely rectification of issues and incidents that adversely affect the quality of observations.

5.4.12 Members who receive and process aircraft-based observations from any source, including AMDAR, ICAO and other aircraft-based observing systems, shall make such observations available to the WIS.

5.4.13 Members who receive, process and make available to the WIS aircraft-based observations from any source, shall make observational metadata available in accordance with the provisions of section 2.5.

APPENDIX 5.5. ATTRIBUTES SPECIFIC TO RADAR WIND PROFILER STATIONS

Notes:
1. Wind profiler observations can be provided by an additional range of remote-sensing systems other than radar wind profilers, such as Doppler lidars, Doppler sodars and Doppler weather radars.
2. Generic description of surface-based remote-sensing profiling techniques and systems is provided in the *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume III, Chapter 5, 5.2; for radar wind profilers in particular see 5.2.2; guidance on operations is available in the *Guide to the Global Observing System* (WMO-No. 488), Part III, 3.9.

5.5.1 Members should consider the establishment of radar wind profiler (RWP) stations in their network of upper-air stations.

5.5.2 **Members operating RWPs shall comply with national regulations for the use of radio frequencies.**

Notes:
1. Extensive information about the use of radio frequencies can be found in the *Handbook on Use of Radio Spectrum for Meteorology: Weather, Water and Climate Monitoring and Prediction* (WMO-No. 1197).
2. Resolution 217 of the World Radiocommunication Conference 1997 (WRC-97) is the basis for frequency allocation for RWPs.
3. Further information is provided in the *Guide to Participation in Radio-frequency Coordination* (WMO-No. 1159).
4. Physical constraints in selecting systems are described in the *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume III, Chapter 5, 5.2.2. The vertical range of a RWP is strongly related to the operating frequency.

5.5.3 **Members operating RWPs shall make horizontal wind vector observations.**

5.5.4 Members operating RWPs should make vertical wind component observations.

5.5.5 **Members shall operate their RWPs continuously so as to acquire and provide horizontal winds at time intervals not exceeding 60 minutes.**

Note: Data acquisition at shorter time intervals, for example, every five or ten minutes, may be preferable or required depending on the user requirements and applications that the observations are intended to support. Users must then be cautious about a potential degradation of data quality under certain atmospheric conditions.

5.5.6 **Members who exchange RWP observations internationally shall report, as quickly as possible, any major incidents they detect to international recipients of observations, and shall report when such incidents have been resolved, in accordance with the incident management systems under WIGOS.**

Notes:
1. A major incident is one that may cause an extended period without observations or with a compromised quality of observations, for example, greater uncertainty or a reduced vertical extent of observations.
2. Some incidents, such as those related to internal factors, may be detected automatically and should be reported without delay to international recipients of observations. Other incidents may be detected with delay or through periodic checks and should be reported accordingly. Automatic incident detection can be performed using either built-in test equipment or external monitoring systems. A centralized system can be used for monitoring the performance and health of RWP systems and networks.
3. It is important to take corrective action in response to incidents, including analysis and recording of the event, as soon as possible.

5.5.7 Members who exchange RWP observations should record and report details of corrective and preventive maintenance in accordance with the provisions of section 2.5.

5.5.8 **Members who exchange RWP observations shall record and report inspection results in accordance with the provisions of section 2.5.**

5.5.9 **Members who exchange RWP observations shall record and report details of calibrations in accordance with the provisions of section 2.5.**

Note: Relevant calibration details, in the case of the spaced antenna method of wind determination, include application of the statistical bias correction.

APPENDIX 5.6. ATTRIBUTES SPECIFIC TO WEATHER RADAR STATIONS

Note: A general description of weather radars is given in the *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume III, Chapter 7; guidance on operations is available in the *Guide to the Global Observing System* (WMO-No. 488), Part III, 3.9.2.1.

5.6.1 Members should establish a network of weather radar stations either nationally or in collaboration with other Members.

Note: The requirement for an exchange of weather radar observations is increasing amongst WMO Members to support information such as composite images.

5.6.2 **Members operating weather radars shall comply with national regulations for the use of radio frequencies.**

Note: Extensive information about the use of radio frequencies is provided in the *Handbook on Use of Radio Spectrum for Meteorology: Weather, Water and Climate Monitoring and Prediction* (WMO-No. 1197) and also in the *Guide to Participation in Radio-frequency Coordination* (WMO-No. 1159).

5.6.3 **Members operating weather radars shall operate radars capable of transmitting and receiving horizontally polarized signals.**

5.6.4 Members should operate weather radars capable of transmitting and receiving both horizontally and vertically polarized signals.

Note: Such radars are generally known as dual-polarization or polarimetric radars.

5.6.5 **Members shall ensure that their weather radars provide observations of the radar reflectivity factor.**

5.6.6 Members should ensure that their single-polarization weather radars provide the following observations:

(a) Radial velocity;

(b) Spectral width.

5.6.7 Members should ensure that their weather radars with dual-polarization capability provide the following observations:

(a) Differential reflectivity;

(b) Cross-polar correlation;

(c) Differential phase;

(d) Specific differential phase.

Notes:

1. Further information about the observations made by weather radars is provided in the *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume III, Chapter 7, Tables 7.1, 7.2 and 7.4.
2. Weather radar operations may pose safety hazards to operators and maintenance personnel as well as to the surrounding community, so the requirement to ensure proper safety procedures is particularly relevant. Typically, on-site safety hazards for weather radars include high voltage, radiation exposure, working in confined spaces, heavy lifting, moving components, climbing and working at heights. Further information is available in the *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume III, Chapter 7, 7.8.1.

5.6.8 Members who operate weather radars should make observations available at least every 15 minutes.

Notes:
1. It is recognized that there may be seasonal differences in the operation of weather radars in Members' territories. The above recommended reporting frequency applies during periods when the radar is in operation.
2. Requirements to make available metadata related to all observations, including weather radar observations, can be found in section 2.5.

5.6.9 Members operating weather radars shall ensure that their observations are quality assured.

Notes:
1. Refer to the provisions in sections 2.4.3 and 2.6.
2. With regard to weather radars, quality control procedures will improve both qualitative and particularly quantitative uses of weather radar observations.
3. To the extent possible, procedures are to include (a) quality control of both internal and external factors in order to enable the characterization of data quality, and (b) a record of the quality control methods used, to be provided to recipients together with the relevant observations. Further information is available in the *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume III, Chapter 7, 7.9.

5.6.10 Members operating weather radars should make weather radar observations available for international exchange.

Note: A standard WMO data format is under development. It will ensure that real-time weather radar observations and metadata can be represented and exchanged in accordance with user requirements.

5.6.11 Members who exchange observations shall provide frequently changing metadata in real time together with the observations, in accordance with the provisions of section 2.5.

Note: Such metadata include information on calibration, timing, beam pointing and other system settings.

5.6.12 Members who exchange weather radar observations shall provide infrequently changing observational metadata, in accordance with the provisions of section 2.5, to the WMO Radar Database.

Note: Members are strongly urged to provide the infrequently changing observational metadata to the WMO Radar Database (https://community.wmo.int/maintaining-wigos-weather-radar-metadata) for all their weather radars, including those whose observations are not exchanged.

5.6.13 Members who exchange weather radar observations internationally shall report any major incidents they detect to international recipients of observations, and shall state when such incidents have been resolved, in accordance with the incident management systems under WIGOS.

Notes:
1. A major incident is one which may cause an extended period without observations or with a compromised quality of observations, for example, greater uncertainty or a reduced vertical extent of observations.
2. Some incidents, such as those related to internal factors, may be detected automatically and should be reported without delay to international recipients of observations. Other incidents may be detected with delay or through periodic checks and should be reported accordingly. Automatic detection is facilitated through the use of built-in test equipment and/or external monitoring systems.

5.6.14 Members should secure their radar coverage by preventing the construction or growth of blockages.

Note: Radar exposure may be compromised, causing reduced coverage, by objects over a wide area, hence negotiations and legal agreements may be required with a range of stakeholders. This is best achieved when establishing a new radar station.

5.6.15 **Members who exchange weather radar observations shall record and report details of corrective and preventive maintenance in accordance with the provisions of section 2.5.**

5.6.16 **Members who exchange weather radar observations shall record and report inspection results in accordance with the provisions of section 2.5.**

5.6.17 **Members who exchange weather radar observations shall record and report details of calibrations in accordance with the provisions of section 2.5.**

Note: Relevant details include calibration variables and their settings or levels, and the terms of the weather radar equation along with the calibration constant.

APPENDIX 5.7. ATTRIBUTES SPECIFIC TO STATIONS CONTRIBUTING TO THE GLOBAL CLIMATE OBSERVING SYSTEM

5.7.1 Members should establish stations as part of Global Climate Observing System (GCOS) Surface Network (GSN) and the GCOS Upper-Air Network (GUAN), in consultation with the GCOS Secretariat.

Notes:
1. Details are available in the *Guide to the GCOS Surface Network (GSN) and GCOS Upper-Air Network (GUAN)* (GCOS-144; WMO/TD No. 1558).
2. Attention needs to be given to data-sparse areas.
3. The GCOS Upper-Air Network is a subset of the upper-air network described in Appendix 5.3.

5.7.2 Members should also establish and sustain the GCOS Reference Upper-air Network (GRUAN) to provide long-term high-quality climate records.

5.7.3 In implementing the observing programme at GSN and GUAN stations, Members should adhere to the GCOS Climate Monitoring Principles in accordance with 2.2.2.2.

5.7.4 When operating GUAN stations, Members should adhere to the following practices:

(a) The reach of soundings should be as high as possible, noting the GCOS requirement for ascents up to a minimum height of 30 hPa, while aiming for 5 hPa where feasible;

(b) In the event of failure, an immediate repeat release is made in order to meet the GUAN requirement for soundings on at least 25 days in each month;

(c) Radiosonde sensors are checked in a controlled environment immediately before use.

Note: The *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume I, Chapter 12, 12.7, provides further details.

GCOS Reference Upper-air Network stations

Note: The practices required of GRUAN sites, as detailed in the *GCOS Reference Upper-air Network (GRUAN): Manual* (GCOS-170, WIGOS Technical Report No. 2013-02), reflect the primary goal of GRUAN: providing reference-quality observations of the atmospheric column while accommodating the diverse capabilities of sites within the network. However, certification of measurement programmes at a GRUAN site goes beyond considering the extent to which the site adheres to the mandatory practices outlined in the GRUAN Manual, and considers the added value that the site brings to the network. The added value is assessed by experts forming the Working Group on the GCOS Reference Upper-air Network, whose judgement is guided by considerations 8.17 to 8.26 (*GCOS Reference Upper-air Network (GRUAN): Manual* (GCOS-170, WIGOS Technical Report No. 2013-02), Chapter 8). The GRUAN Manual is supplemented by a more detailed *GCOS Reference Upper-air Network (GRUAN): Guide* (GCOS-171, WIGOS Technical Report No. 2013-03), which provides guidelines on how the protocols detailed in the GRUAN Manual might be achieved, and by a series of technical documents available from the GRUAN website at https://www.gruan.org

5.7.5 **Members with certified GRUAN stations shall follow the practices and procedures as detailed in the *GCOS Reference Upper-air Network (GRUAN): Manual* (GCOS-170, WIGOS Technical Report No. 2013-02).**

5.7.6 **Stations contributing to GRUAN shall undergo the GRUAN site assessment and certification process.**

5.7.7 Stations within GRUAN shall collect and archive sufficient raw data and metadata to enable the processing, and future reprocessing, of measurements, at a centralized processing facility, into a reference measurement.

Note: As a minimum, GRUAN station metadata include the entire measurement procedure, the uncertainty of the measurement and how it is tied to an internationally accepted traceable standard.

5.7.8 Members shall ensure the long-term homogeneity of measurement series at GRUAN stations.

5.7.9 Members shall operate their GRUAN stations in such a way as to ensure the homogeneity of measurements across the GRUAN network.

5.7.10 Members shall ensure that their GRUAN sites perform pre-launch ground checks for balloon-borne systems.

Note: Other instruments that provide vertical profiles extending from the surface require regular checks to assure correct operation.

5.7.11 Members shall ensure that GRUAN sites provide high-quality parallel measurements to validate the derivation of the measurement uncertainty.

Note: The *GCOS Reference Upper-air Network (GRUAN): Manual* (GCOS-170, WIGOS Technical Report No. 2013-02) and the *GCOS Reference Upper-air Network (GRUAN): Guide* (GCOS-171, WIGOS Technical Report No. 2013-03) provide detailed instructions and guidance.

APPENDIX 5.8. ATTRIBUTES SPECIFIC TO OBSERVATIONS OF ESSENTIAL CLIMATE VARIABLES

Notes:

1. These Essential Climate Variables (ECVs) were identified by the Commission for Climatology and by the Global Climate Observing System (GCOS); details are provided in *The Global Observing System for Climate: Implementation Needs* (GCOS-200), which describes the parameters to be measured for each ECV.
2. See also 2.2.2.2 Climate monitoring principles of the Global Climate Observing System in section 2.
3. Requirements for the ECVs are provided by the RRR process for the application area Climate Monitoring (GCOS). Appendix 2.3 provides further details on the RRR process.
4. For climate purposes long-term timeseries are needed in a timely manner.

5.8.1 **Members making observations for climate applications shall observe the following mandatory ECVs:**

(a) Surface observations: atmospheric pressure, air temperature, humidity (water vapour), surface wind speed and direction, and precipitation;

(b) Upper-air observations: air temperature, humidity (water vapour) and wind speed and direction.

Note: Details on the observation of these ECVs are given in Appendices 5.1-5.6.

5.8.2 **Members shall exchange both historic data archives and current observations of the mandatory ECVs with a tentative maximum delay of one year.**

5.8.3 Members making observations for climate applications should observe some or all of the following ECVs.

(a) Surface land observations: surface radiation budget, clouds, lightning, snow;

(b) Surface marine observations: sea-surface temperature, sea level, sea state, ocean-surface heat flux, sea ice;

(c) Observations made by the observing component of the Global Atmospheric Watch: carbon dioxide, methane and other greenhouse gases, ozone, precursors (supporting the aerosol and ozone ECVs), aerosol properties;

(d) Observations made by the WMO Hydrological Observing System: river discharge, lakes;

(e) Observations made by the observing component of the Global Cryosphere Watch: glaciers, ice sheets and ice shelves, permafrost, snow, sea ice.

Note: Details on the observation of these ECVs are given in Appendices 5.1–5.6., and Chapters 6, 7 and 8.

5.8.4 Members should exchange both historic data archives and current observations of the ECVs listed in 5.8.3 with a tentative maximum delay of one year.

5.8.5 Members making observations for climate applications should observe the following remaining ECVs, if feasible.

(a) Atmospheric observations: Earth radiation budget;

(b) Ocean observations: subsurface temperature, sea-surface salinity, subsurface salinity, surface currents, subsurface currents, surface stress, oxygen, nutrients, inorganic carbon, transient tracers, nitrous oxide, ocean colour, plankton, marine habitat properties;

(c) Terrestrial observations: groundwater, Fraction of Absorbed Photosynthetically Active Radiation (FAPAR), leaf area index, albedo, land-surface temperature, above-ground biomass, land cover, soil carbon, fire, anthropogenic greenhouse-gas fluxes, latent and sensible heat fluxes.

5.8.6 Members should exchange both historic data archives and current observations of the ECVs listed in 5.8.5 with a tentative maximum delay of one year.

Notes:

1. These are the remaining ECVs that do not have additional requirements listed in this Manual and are not generally observed by NMHSs.
2. More detailed requirements can be found in *The Global Observing System for Climate: Implementation Needs* (GCOS-200) and in the RRR process for the Climate Monitoring (GCOS) application area.

ATTACHMENT 5.1. METEOROLOGICAL VARIABLES TO BE OBSERVED

No.	*Variables*	*Surface synoptic/basic observations on land*	*Surface marine meteorological observations*	*Surface observations for climate applications*	*Surface observations for aeronautical meteorology*	*Surface observations for agricultural meteorology*	*Upper-air observations*
	[g]	[a]	[b] [f] [i]	[c]	[d]	[e]	[h]
1	Atmospheric pressure	X	X	X	X [8]	X	[X] [9]
2	Pressure tendency and characteristics	[X]	X	X			
3	Air temperature	X	X	X	X	X	[X]
4	Extreme temperatures	[X]	X	X			
5	Humidity	X	X	X	X	X [12]	[X]
6	Surface wind/Horizontal wind	X	X	X	X	X	[X]
7	Wind gust speed	[X]	[X]	[X]	X	[X]	
8	Wind turbulence type and intensity						[X]
9	Present and past weather	{X}	{X}	{X}	{X}	{X}	
10	Special phenomena	[{X}]	[{X}]	[{X}]			
11	Lightning (*)	[X]	[X]	X	[X]		[X]
12	Cloud amount and type (*)	{X}	{X}	{X}	{X} [2]	X [10]	[X]
13	Extinction profile/cloud base (*)	{X}	{X}	X	X [5]		[X]
14	Visibility	{X}	X	X	X [3]	X	
15	Precipitation, amount	[X]	X	X		X	
16	Precipitation, yes/no	{X}	X				
17	Intensity of precipitation	[X]			[X] [4]		
18	Evaporation and transpiration					X	
19	State of the ground	[X]		X	X [13]		
20	Snow depth	[X]	[X] [1]	X	[14]		
21	Soil temperature	[X]	N/A	X		X	
22	Soil moisture			X		X	
23	Sunshine duration and/or solar radiation	[X]	[X]	X		X [11]	
24	Net solar radiation		[X]	X			

No.	*Variables*	*Surface synoptic/basic observations on land*	*Surface marine meteorological observations*	*Surface observations for climate applications*	*Surface observations for aeronautical meteorology*	*Surface observations for agricultural meteorology*	*Upper-air observations*
25	Radiation (various components)			X			
26	Sea-surface temperature		X	X	X [15]		
27	Wave period		X				
28	Wave height		X	X	X [15]		
29	Wave movement direction		X		X [15]		
30	Sea ice and/or icing of ship superstructure		[X]	X			
31	Course and speed of a mobile sea station/platform		X		X		
32	Sea level		[X]	X			
33	Height of inversion layer/height of mixing layer (*)						[X]
34	Rate of ice accretion						[X]
35	Additional variables for agriculture -see the list below					[X]	
36	Ocean surface heat flux		[X]	X			

Notes:

X This symbol indicates that observation of the variable is mandatory;

{X} This symbol indicates that a variable observed at a manual station may not be feasibly observed at an automatic station;

[X] This symbol indicates that the variable is to be observed, if possible, or if specified by resolutions of the regional association;

[a] WMO global requirements for weather and climate applications associated with the World Weather Watch;

[b] WMO global requirements for weather, climate and ocean applications. All variables measured in the atmosphere or sea surface are meteorological observations required for operational purposes;

[c] Requirements of the Commission for Climatology, supported by GCOS (see *Guide to Climatological Practices* (WMO-No. 100) and *The Global Observing System for Climate: Implementation Needs* (GCOS-200));

[d] Requirements of the Commission for Aeronautical Meteorology, supported by ICAO;

[e] Requirements of the Commission for Agricultural Meteorology (see *Guide to Agricultural Meteorological Practices* (WMO-No. 134));

[f] Such an observation may be made from coastal stations on land and surface marine stations;

[g] If the technology is available (manned and automatic);

[h] WMO global requirements for weather and climate applications associated with the World Weather Watch. In most cases, entries in this column indicate vertical profile observations of the relevant variables;

[i] Certain stations/platforms may not have the capability to measure all mandatory elements due to technical constraints;

[1] Snow coverage of sea ice;
[2] Not all cloud types, only those related to turbulence (Cumulonimbus and Towering Cumulus);
[3] Visibility for aeronautical purposes (differs from the Meteorological Optical Range (MOR));
[4] Included as a component of present weather in subjective terms;
[5] Cloud base only;
[6] For helidecks on ships;
[7] Surface radiation budget;
[8] QNH and/or QFE;
[9] To determine altitude;
[10] Cloudiness only;
[11] For agricultural meteorology, also "photoperiod";
[12] Including leaf wetness and dew;
[13] The state of the runway is a different variable from the state of the ground, which is reported in METAR/SPECIs;
[14] The requirement for aviation is to report snow intensity as part of the present weather variable. Also, snow amount on the runway is reported as supplementary information for state of the runway in terms of depth of deposit and friction coefficient. This requirement will hold until 4 November 2020 (inclusion is conditional, depending on meteorological conditions or method of observation; see *Technical Regulations* (WMO-No. 49), Volume II, with explanations in ICAO Doc 8896);
[15] Sea-surface temperature and state of the sea or significant wave height are reported as supplementary information (inclusion is conditional, depending on meteorological conditions or method of observation; see: *Technical Regulations* (WMO-No. 49), Volume II, with explanations in ICAO Doc 8896);
(*) in fact: upper-air observations.

Additional variables for agriculture:

1. At stations supporting agricultural meteorology, Members are to conduct an observing programme that, in addition to the other meteorological observations being made, includes some or all of the following:
   (a) Observations of the physical environment:
      (i) Temperature and humidity of the air at different levels in the layer adjacent to the ground (from ground level up to about 10 m above the upper limit of prevailing vegetation), including extreme values of these meteorological elements;
      (ii) Soil temperature at depths of 5, 10, 20, 50 and 100 cm and at additional depths for special purposes and in forest areas;
      (iii) Soil water (volumetric content) at 5, 10, 20, 50 and 100 cm and at additional depths for special purposes and deep soils, with at least three replications when the gravimetric method is used;
      (iv) Turbulence and mixing of air in the lower layer (including wind measurements at different levels);
      (v) Hydrometeors and water-balance components (including hail, dew, fog, evaporation from soil and from open water, transpiration from crops or plants, rainfall interception, runoff and water table);
      (vi) Sunshine duration, global and net radiation as well as the radiation balance over natural vegetation, and crops and soils (over 24 hours);
      (vii) Observations of weather conditions causing direct damage to crops, such as frost, hail, drought, floods, gales and extremely hot, dry winds;
      (viii) Observations of damage caused by sandstorms and duststorms, rainfall erosivity, atmospheric pollution and acid deposition as well as forest, bush and grassland fires;
      (ix) Observations of greenhouse gas concentrations and fluxes in the context of climate change processes.
   (b) Observations of a biological nature:
      (i) Phenological observations;
      (ii) Observations on growth (as required for the establishment of bioclimatic relationships);
      (iii) Observations on qualitative and quantitative yield of plant and animal products;

(iv) Observations of direct weather damage to crops and animals (adverse effects of frost, hail, drought, floods and gales);
(v) Observations of damage caused by disease and pests;
(vi) Observations of damage caused by sandstorms, duststorms and atmospheric pollution, as well as forest, bush and grassland fires.

2. Members are to make agricultural meteorological observations of the physical environment at the main standard times.
3. Members are to make agricultural meteorological observations of a biological nature regularly, at least every two or three days, or as frequently as significant changes occur.

No.	*Variables*	*Essential Climate Variable (ECV) for GCOS*	*Remarks*
		[a]	[c]
1	Atmospheric pressure	ECV	Pressure at station level and reduced to mean sea level (MSL)
2	Pressure tendency and characteristics		Derived from continuous measurement of atmospheric pressure at station level
3	Air temperature	ECV	At different heights, including grass minimum temperature
4	Extreme temperatures		Minimum and maximum air temperature
5	Humidity	ECV	Dew- or ice-point temperature, mass mixing ratio, liquid water content, relative humidity directly measured or derived from dew-point temperature and air temperature, water vapour pressure.
6	Surface wind/Horizontal wind	ECV	Horizontal component of 3D wind vector at 10 m above surface, expressed in polar (speed and direction) or Cartesian coordinates (North-South and East-West). Averaged over 10 minutes
7	Wind gust speed		From the continuous measurement of surface wind
8	Wind turbulence type and intensity		
9	Present and past weather		Qualitative description of observable phenomena in the atmosphere including precipitation, suspended or blowing particles, and other designated optical phenomena or electrical manifestations, as described in the *International Cloud Atlas: Manual on the Observation of Clouds and Other Meteors* (WMO-No. 407), the *Guide to Instruments and Methods of Observation* (WMO-No. 8) and, for aeronautical applications, in the *Technical Regulations* (WMO-No. 49), Volume II.
10	Special phenomena		Further guidance for observation of special phenomena is provided in the *Guide to the Global Observing System* (WMO-No. 488), Part III, 3.2.2.2.11.
11	Lightning (*)	ECV	
12	Cloud amount and type (*)	ECV	Cloud coverage and type as defined in the *International Cloud Atlas: Manual on the Observation of Clouds and Other Meteors* (WMO-No. 407)
13	Extinction profile/cloud base (*)	ECV	Cloud bases, derived from extinction profile
14	Visibility		Equal to MOR, defined as $3/\sigma$
15	Precipitation, amount	ECV	Expressed in the liquid equivalent {Mass/area} or {Volume/area}. May be derived from continuous measurement of intensity of precipitation; if less than 0.01 mm, it should be indicated as "trace"

No.	*Variables*	*Essential Climate Variable (ECV) for GCOS*	*Remarks*
16	Precipitation, yes/no	ECV	If intensity of precipitation exceeds 0.001 mm/h
17	Intensity of precipitation		Expressed in the liquid equivalent {Mass/area/period} or {Volume/area/period}. If less than 0.01 mm/h, it should be indicated as " trace"
18	Evaporation and transpiration	ECV	
19	State of the ground		Snow coverage
20	Snow depth	ECV	Also water equivalent of snow
21	Soil temperature		At different depths
22	Soil moisture	ECV	At different depths
23	Sunshine duration and/or solar radiation		Duration based on the period sunshine is detected with incoming direct radiation of 120 W/m^2
24	Net solar radiation	ECV (S, U) [1]	Expressed in {Power/area}
25	Radiation (various components)	ECV	Defined by the Baseline Surface Radiation Network (BSRN) programme
26	Sea-surface temperature	ECV (S) [b]	Metadata is important for this variable because there are various methods of observation which produce different results, for example, skin temperature or bulk temperature over 2 m
27	Wave period	ECV (S) [b][2]	
28	Wave height	ECV (S) [b][2]	
29	Wave movement direction	ECV (S) [b][2]	In polar coordinates with reference to True North
30	Sea ice and/or icing of ship superstructure	ECV (S) [b]	
31	Course and speed of a mobile sea station/platform		In polar coordinates with reference to True North
32	Sea level	ECV (S) [b]	With reference to MSL, also for coastal observations
33	Height of inversion layer/ height of mixing layer (*)		
34	Rate of ice accretion		
35	Additional variables for agriculture, see list above		
36	Ocean surface heat flux	ECV	

Notes:

[a] GCOS requirements: S = surface, U = upper-air; see *The Global Observing System for Climate: Implementation Needs* (GCOS-200), and https://public.wmo.int/en/programmes/global-climate-observing-system/essential-climate-variables;

[b] This variable is also an Essential Ocean Variable (EOV) as specified by the Global Ocean Observing System (GOOS); see http://www.goosocean.org/;

[c] If the technology is available (manned and automatic);

[1] For surface: Surface Radiation Budget; for upper-air: Earth Radiation Budget;

[2] This variable is part of ECV and EOV, described as "Sea state";

(*) in fact: upper-air observations.

6. ATTRIBUTES SPECIFIC TO THE OBSERVING COMPONENT OF THE GLOBAL ATMOSPHERE WATCH

Note: The provisions of sections 1, 2, 3 and 4 are common to all WIGOS component observing systems, including GAW. The provisions in this section are specific to GAW.

6.1 REQUIREMENTS

6.1.1 Members should perform the observations of atmospheric composition and related physical parameters using a combination of surface-based stations and platforms (fixed stations, mobile platforms and remote-sensing) and space-based platforms.

6.1.2 When developing their GAW stations, Members should use the requirements from the RRR process, particularly in the areas of forecasting of atmospheric composition, and monitoring of atmospheric composition and atmospheric composition for urban applications.

Notes:

1. The user requirements are reviewed on a regular basis through the RRR process by the Scientific Advisory Groups (SAGs) for each variable, in consultation with the user community and with input from Members. The RRR process is described in section 2.2.4 and Appendix 2.1.
2. Scientific Advisory Groups exist for the six GAW focal areas and their terms of reference are defined by the Research Board.

6.1.3 Members should follow the data quality objectives specified by the GAW Programme for the individual variables observed.

6.1.4 Members should establish and operate their GAW stations in accordance with the specifications provided in the *WMO Global Atmosphere Watch (GAW) Implementation Plan: 2016-2023* (GAW Report No. 228), Annex B: Station and network definitions and operations.

6.1.5 **Members operating GAW stations shall undertake long-term and uninterrupted operation with the stability and continuity of data collection required for the purposes outlined in 6.2.1.**

6.2 DESIGN, PLANNING AND EVOLUTION

6.2.1 Members should design, plan and further develop their GAW observing network and stations to address user requirements, in particular those that concern key environmental issues and application areas, including but not limited to changes in the weather and climate related to human influence on atmospheric composition, particularly on greenhouse gases, ozone and aerosols; impacts of air pollution on human and ecosystem health and issues involving long-range transport and the deposition of air pollution; and changes in UV radiation as a consequence of changes in atmospheric ozone amounts and climate.

6.2.2 Members should contribute observations through operating or supporting suitable platforms at GAW stations and/or through contributing networks.

6.2.3 **When doing so, Members shall register their contribution in GAWSIS and submit their observations to the relevant world data centre.**

Note: The GAW Station Information System is the official catalogue for monitoring sites, platforms or stations operating within GAW and related programmes, providing station metadata and serving as the clearing house for unique station identifiers. The GAW Station Information System represents the metadata source for OSCAR for GAW observations.

6.2.4 **Members operating a contributing network shall provide a description of the network, register the stations in GAWSIS and provide corresponding metadata.**

6.2.5 Members should ensure that the frequency and spacing of the various observations is suited to the temporal and spatial requirements of the specific issues addressed in section 6.2.1.

6.3 INSTRUMENTATION AND METHODS OF OBSERVATION

6.3.1 General requirements of instruments

Members should use recommended types of instrument and method of observation for variables observed at their stations, and should follow further available guidance.

Notes:
1. Guidance is provided in the Standard Operating Procedures (SOPs) and measurement guidelines.
2. Instruments suitable for use at GAW sites are defined by the SAGs for each parameter, in terms of stability, precision and accuracy.
3. Standard operating procedures describe the standard approach to operating such instruments.
4. The measurement guidelines describe the standard approach for this kind of measurement regardless of the instrument.

6.3.2 Calibration and traceability

6.3.2.1 **Members shall perform calibrations and maintain traceability to the GAW primary standards, where available.**

Notes:
1. The GAW primary standard is a single network standard, assigned by WMO for each individual variable. In the case of contributing networks, network observations are traceable to the network standard, which in turn is traceable to the GAW primary standard.
2. Details of calibrations are specified by the SOPs and measurement guidelines.

6.3.2.2 Members should utilize GAW central facilities to sustain the global compatibility of observations.

Note: The GAW central facilities include: central calibration laboratories, world calibration centres, regional calibration centres and quality assurance/science activity centres.

6.4 OPERATIONS

6.4.1 Monitoring observing system implementation

6.4.1.1 **Members shall monitor the operation of GAW stations for which they are responsible and shall ensure that they follow the relevant procedures for quality assurance and data submission. Members shall seek assistance from central facilities, SAGs and expert teams if operational problems cannot be solved locally.**

Note: The procedures to be used in monitoring the operation of GAW are determined by the Research Board in consultation with the participating Members.

6.4.1.2 Members should systematically monitor compliance with GAW regulations, in collaboration with relevant constituent bodies and the WMO Secretariat, in order to identify critical cases of non-compliance (deficiencies) and undertake measures for their timely resolution.

6.4.2 **Quality assurance**

6.4.2.1 Members should follow specified quality assurance practices and procedures.

Note: Details are given in the GAW SOPs and measurement guidelines and in further documents provided by the SAGs, expert teams and central facilities.

6.4.2.2 **Members shall maintain detailed metadata records in accordance with procedures and practices specified in this Manual.**

6.4.2.3 Members should participate in independent evaluations of quality of observations, including intercomparisons and system audits, as appropriate for the observed variables.

6.4.2.4 **Members shall allow world data centres to perform an independent evaluation of the data quality of their observations.**

6.4.3 **Data and metadata representation and format**

6.4.3.1 **Members shall submit their observational data and associated metadata to the relevant world data centres for the variables observed at the station within agreed time limits.**

6.4.3.2 **Members shall use the formats specified by the relevant world data centre when submitting their observational data and metadata.**

6.5 **OBSERVATIONAL METADATA**

Note: The general provisions on observational metadata are specified in section 2.5.

6.5.1 **Members shall provide metadata associated with the instrumentation, site or platform, and calibration history as requested by the world data centre for each parameter and by GAWSIS.**

6.5.2 **Members shall provide additional metadata required by GAWSIS and by any world data centre to which they contribute to enable the understanding of their observations.**

6.6 **QUALITY MANAGEMENT**

Note: The general regulations on quality management are specified in section 2.6.

6.7 **CAPACITY DEVELOPMENT**

Note: General provisions for capacity development are provided in sections 2.7 and 4.8.

6.7.1 Members unable to implement required standards should establish agreements with appropriate central facilities or establish partnerships with more experienced stations in the form of station twinning.

Note: In some regions of the world, and for some GAW variables, where there is a clear lack of capacity, Members may be requested to support a station, or existing stations may be approached to become part of GAW. Such requests and invitations come after approval by the appropriate SAG(s).

6.7.2 Members should use the GAW Training and Education Centre (GAWTEC) programme, as available, for capacity-building and staff training in measurement of the specific GAW variables.

7. ATTRIBUTES SPECIFIC TO THE WMO HYDROLOGICAL OBSERVING SYSTEM

Note: The provisions of sections 1, 2, 3 and 4 are common to all WIGOS component observing systems, including WHOS. The provisions of this section are specific to WHOS.

7.1 REQUIREMENTS

7.1.1 **Members shall establish and operate a hydrological observing system according to their national requirements.**

7.1.2 Members should also operate their hydrological observing systems to address the requirements of the RRR process, in particular for the hydrology application area.

Notes:

1. A hydrological observing system includes networks of hydrological observing stations, as defined in the *Technical Regulations* (WMO-No. 49), Volume III, Chapter D.1.1. Such observing stations should make observations of the elements described in Chapter D.1.2.
2. Information on hydrological data transmission can be found in the *Technical Regulations* (WMO-No. 49), Volume III, Chapter D.1.4, [D.1.4.]1.2, which states: "Transmission facilities should be organized for the international exchange of hydrological data, forecasts and warnings on the basis of bilateral or multilateral agreement." Further provisions for data transmission and international exchange through the WIS are laid out in the *Technical Regulations* (WMO-No. 49), Volume I, Part II, the *Manual on the WMO Information System* (WMO-No. 1060) and the *Manual on the Global Telecommunication System* (WMO-No. 386).

7.1.3 **Members shall provide on a free and unrestricted basis those hydrological data and products that are necessary for the provision of services for the protection of life and property, and the well-being of all peoples.**

7.1.4 Members should also provide, where available, additional hydrological data and products that are required by WMO Programmes and by Members as specified in paragraph 7.1.2.

7.1.5 **At the global level, WHOS shall give Members access to near-real-time hydrological observations from all Members.**

Note: Currently, many Members are making such observations publicly available on the Internet.

7.1.6 Members who make near-real-time hydrological observations publicly available on the Internet should provide these observations to WHOS.

7.2 DESIGN, PLANNING AND EVOLUTION

Note: Design, planning and evolution is common to all WIGOS component observing systems.

Members should design and plan their observing network bearing in mind the review of the current and planned WHOS capabilities, undertaken as outlined in the RRR described in section 2.2.4.

7.3 INSTRUMENTATION AND METHODS OF OBSERVATION

7.3.1 General requirements of instruments

7.3.1.1 Members should equip their stations with properly calibrated instruments and should arrange for these stations to follow adequate observational and measuring techniques to ensure that the measurements and observations of the various hydrological elements are accurate enough to address the needs of hydrology and other application areas.

Note: *Technical Regulations* (WMO-No. 49), Volume III, provides that Members should use instruments for measurement of stage (water level) in conformity with the specifications of its annex, section II: Water-level measuring devices.

7.3.1.2 Members should ensure that the uncertainty in the observation of the stage (water level) of rivers, estuaries, lakes and reservoirs does not exceed:

(a) In general, 10 mm at the 95% confidence level;

(b) Under difficult conditions, 20 mm at the 95% confidence level.

Note: Stage (water level) observations are used primarily as an index for computing streamflow discharge when a unique relation exists between stage (water level) and discharge.

7.3.2 Stage and discharge observations from hydrometric stations

Note: *Technical Regulations* (WMO-No. 49), Volume III, provides that Members should establish and operate hydrometric stations for measuring stage (water level), velocity and discharge in conformity with the specifications of its annex, section VI: Establishment and operation of a hydrometric station.

7.3.2.1 Members should ensure that the number of discharge measurements at a stream gauging station allows the rating curve for the station to be defined at all times.

Notes:
1. *Technical Regulations* (WMO-No. 49), Volume III, provides that Members should use the methods for determining the stage-discharge relation (rating curve) of a station as specified in its annex, section VII: Determination of the stage-discharge relation.
2. *Technical Regulations* (WMO-No. 49), Volume III, provides that Members should ensure, when undertaking moving-boat discharge measurements, that equipment and operational procedures are as specified in its annex, section XII: Discharge measurements by the moving-boat method.

7.3.2.2 Members should measure river discharge to an accuracy commensurate with flow and local conditions. Percentage uncertainty of the discharge measurement should not exceed:

(a) In general, 5% at the 95% confidence level;

(b) Under difficult conditions, 10% at the 95% confidence level.

Notes:
1. *Technical Regulations* (WMO-No. 49), Volume III, provides that Members should evaluate the uncertainty in discharge measurements in conformity with the specifications in its annex, section VIII: Estimation of uncertainty of discharge measurements.
2. Discharge measurements are taken to establish and verify the stability of a rating curve. Stage (water level) observations are converted to estimates of discharge using the rating curve on an ongoing basis.

7.3.3 Calibration procedures

Notes:
1. *Technical Regulations* (WMO-No. 49), Volume III, provides that Members should adhere to the specifications of facilities, equipment and procedure for the calibration of current meters as specified in its annex, section I: Calibration of current meters in straight open tanks.
2. *Technical Regulations* (WMO-No. 49), Volume III, provides that Members should ensure that operational requirements, construction, calibration and maintenance of rotating element current meters are as specified in its annex, section IV: Rotating element type current meters.

Members should recalibrate acoustic velocity meters on a routine basis to ensure stability of the calibration, using measurement standards traceable to international or national standards. Where no such standards exist, Members should record the basis used for calibration or verification.

Note: Additional information pertaining to the calibration of instruments can be found in the *Guide to Hydrological Practices* (WMO-No. 168), Volume I, 2.3.4, and in the *Manual on Stream Gauging* (WMO-No. 1044), Volume I, 5.3, 6.4 and 6.5.

7.4 OPERATIONS

7.4.1 Observing practices

7.4.1.1 Members should collect and preserve their hydrological records.

7.4.1.2 Members should make the necessary arrangements to facilitate the retrieval and analysis of their hydrological observations by means of automatic data-processing equipment.

7.4.1.3 Where automatic registration is not available, Members should ensure that the observations of elements for hydrological purposes are made at regular intervals appropriate for the elements and their intended purposes.

7.4.1.4 Members should maintain in their archives an up-to-date inventory of their hydrological observations.

7.4.1.5 Members should generally ensure uniformity in observation times within a catchment area.

7.4.1.6 Members should select the time units used in processing hydrological data for international exchange from the following:

(a) The Gregorian calendar year;

(b) The months of this calendar;

(c) The mean solar day, from midnight to midnight, according to the zonal time, when the data permit;

(d) Other periods by mutual agreement in the case of international drainage basins or drainage basins in the same type of region.

7.4.1.7 For hydrometric stations where data are internationally exchanged, Members should process the following characteristics for each year:

(a) Maximum instantaneous and minimum daily mean values of stages (water levels) and discharge;

(b) Mean daily stages (water levels) and/or mean daily discharges.

7.4.1.8 For rivers under flood conditions or where there are variable controls, Members should make special measurements at intervals frequent enough to define the hydrograph.

7.4.1.9 When sudden and dangerous increases in river levels occur, Members should make and report observations as soon as possible regardless of the usual time of observation, to meet the intended operational use.

7.4.1.10 Members should measure and store stage (water level) observations as instantaneous values rather than averaged values.

7.4.2 Quality control

7.4.2.1 Members should maintain detailed records for each station and for each parameter containing metadata related to the measurements, maintenance and calibration of equipment.

7.4.2.2 Members should perform periodic audits of their stations and collected data.

7.4.2.3 Members should ensure that recorded hydrological observations are converted to a form suitable for archiving and retrieval.

Note: Observations may initially be recorded using various media from paper to electronic form. As computer archiving has become a standard practice for most Members, it is advantageous to convert data to the required format early in the process.

7.4.2.4 Members should ensure that their data undergo, at various stages, a range of checks to determine their uncertainty and correctness.

7.4.2.5 With accelerating developments in technology, Members should ensure that data-processing and quality control systems are well-organized and that the relevant staff are trained to understand and use them.

Note: Data are collected and recorded in many ways, ranging from the manual reading of simple gauges to a variety of automated data-collection, transmission and filing systems.

7.4.2.6 Members should consider the adoption of a quality management system, as described in section 2.6.

Note: Organizations usually employ an accredited certification agency to provide independent verification.

7.4.2.7 Members should undertake data processing and quality control as described in relevant publications.

Note: Such publications include the *Guide to Hydrological Practices* (WMO-No. 168), Volume I, Chapter 9, the *Manual on Flood Forecasting and Warning* (WMO-No. 1072), Chapter 6, and the *Manual on Stream Gauging* (WMO-No. 1044), Volume II, Chapter 6.

7.4.3 Observations and observational metadata reporting

7.4.3.1 Members should ensure, when providing hydrological information for international purposes, that open text or appropriate code forms are used as specified in bilateral or multilateral agreements.

7.4.3.2 Members should ensure that transmission facilities are organized for the international exchange of hydrological observations on the basis of bilateral or multilateral agreements.

7.4.3.3 In order to make data globally available for real-time exchange and discovery, access and retrieval, Members should report stage and discharge observations in compliance with WIS metadata standards.

Notes:
1. The WMO Information System may also be used for access to hydrological observations not required in real time.
2. The regulations governing exchanges in international code forms are specified in the *Manual on Codes* (WMO-No. 306), Volumes *I.1*, *I.2* and *I.3*.
3. Coded information exclusively for bilateral or multilateral exchange amongst Members may be in other forms by mutual agreement.

7.4.4 Incident management

Note: General provisions for incident management are provided in section 2.4.5.

7.4.5 Change management

Note: General provisions for change management are provided in section 2.4.6.

7.4.6 Maintenance

7.4.6.1 Members should determine the frequency and timing of visits to recording stations on the basis of the length of time that the station can be expected to function without maintenance and the uncertainty requirements of the data.

Notes:
1. There is a relation between the frequency of the visits and the resultant quality of the data collected. Too long a time between visits may result in frequent recorder malfunction and thus in loss of data, while frequent visits are both time-consuming and costly.
2. Some data collection devices may suffer a drift in the relationship between the variable recorded and that represented by the recorded value. An example of this is a non-stable stage-discharge relationship.
3. Two visits per year are considered an absolute minimum. More frequent visits are recommended to decrease the potential loss of data and to avoid data being severely affected by problems such as silting, vandalism or seasonal vegetative growth.

7.4.6.2 Members should schedule periodic visits to the station to recalibrate the equipment or the measurement equations.

7.4.6.3 Members should periodically inspect stations using trained personnel to ensure the correct functioning of instruments.

7.4.6.4 Members should ensure that a formal written inspection is done routinely, preferably each year, to check overall performance of instruments and local observer, if applicable.

7.4.6.5 Members, when routinely inspecting sites, should:

(a) Measure gauge datum to check for and record any changes in levels;

(b) Check the stability of the rating curve and review the relationships between the gauges and permanent level reference points to verify that no movement of the gauges has taken place;

(c) Review the gauging frequency achieved and the rating changes identified;

(d) Undertake a number of maintenance activities as described in sections 7.4.6.8 and 7.4.6.9.

Note: It is vital, for the quality of data, that resources for gauging be allocated and prioritized using rigorous and timely analysis of the probability and frequency of rating changes.

7.4.6.6 Members should ensure that maintenance activities are conducted at data-collection sites at intervals sufficient to ensure that the quality of the data being recorded is adequate.

7.4.6.7 Members should ensure that such activities are conducted by the observer responsible for the sites, if there is one. Members should also ensure that maintenance activities are occasionally performed by an inspector.

7.4.6.8 Members should undertake the following maintenance activities at all collection sites:

(a) Service the instruments;

(b) Replace or upgrade instruments, as required;

(c) Retrieve or record observations;

(d) Perform the recommended checks on retrieved records;

(e) Carry out general checks of all equipment, for example, transmission lines;

(f) Check and maintain the site in accordance with the recommended specifications;

(g) Check and maintain access to the station;

(h) Record, in note form, all of the above activities;

(i) Comment on changes in land use or vegetation;

(j) Clear debris and overgrowth from all parts of the installation.

7.4.6.9 Members should undertake the following maintenance activities at discharge collection sites:

(a) Check the bank stability, as necessary;

(b) Check the level and condition of gauge boards, as necessary;

(c) Check and service the flow-measuring devices such as cableways, as necessary;

(d) Check and repair control structures, as necessary;

(e) Regularly survey cross-sections and take photographs of major station changes after events or changes in vegetation or land-use;

(f) Record, in note form, all of the above activities and their results;

(g) Inspect the area around or upstream from the site, and record any significant land-use or other changes in related hydrological characteristics, such as ice.

Note: Further details are found in the *Manual on Stream Gauging* (WMO-No. 1044), Volume I, 4.8.8.

7.4.6.10 Members should have a well-trained technician or inspector visit stations immediately after every severe flood in order to check the stability of the river section and the gauges. Members should train a local observer, if there is one, to check for these problems and communicate them to the regional or local office.

7.4.6.11 Members should not programme flood gaugings as part of a routine inspection trip because of the unpredictable nature of floods.

7.4.6.12 Members should establish a flood action plan prior to the beginning of the storm or flood season and should specify priority sites and types of data required.

Note: If flood gaugings are required at a site, the preparations would ideally be made during the preceding dry or non-flood season so that all is ready for the annual flood season.

7.4.6.13 Members should consider undertaking the following additional measures if severe flooding is likely:

(a) Upgrade site access (helipad, if necessary);

(b) Equip a temporary campsite with provisions;

(c) Store and check gauging equipment;

(d) Protect instrumentation, such as stage recorders, by taking flood-proofing measures.

7.4.6.14 Following the recession of floodwaters, Members should pay particular attention to ensuring the safety and security of the data-collection site and to restoring the normal operation of on-site instrumentation.

Note: In some cases, redesign and reconstruction of the site may be required. Such work would ideally take into account information obtained as a result of the flood.

7.4.7 Calibration procedures

Note: Determination of a rating curve is described in section 7.3.2. Calibration procedures for current meters are described in section 7.3.3.

7.5 OBSERVATIONAL METADATA

Notes:
1. Provisions for describing, recording and retaining, and for exchanging and archiving observational metadata are provided in section 2.5. These apply to all WIGOS component observing systems including WHOS. Further provisions specific to WHOS are stated here.
2. The observational metadata are detailed in Appendix 2.4 and in the *WIGOS Metadata Standard* (WMO-No. 1192).
3. Within an organization or country, a hydrological information system, a station registration file and a historical operation file (as indicated in the *Guide to Hydrological Practices* (WMO–No. 168), Volume I, Chapter 2, 2.5.2.2, and Chapter 10, 10.2) or similar repositories may be used as a convenient means to compile a set of metadata about a hydrological station and its observations.

7.5.1 Members who use their own station identifiers for hydrological stations should maintain the means to match these with the WIGOS station identifiers, as specified in section 2.4 and Attachment 2.1.

7.5.2 Members should collect and record additional observational metadata identifying the purpose of the station in accordance with the provisions in section 2.5.

Note: Further details are found in the *Guide to Hydrological Practices* (WMO-No. 168), Volume I, Chapter 10.

7.6 QUALITY MANAGEMENT

Notes:

1. Provisions for the implementation of quality management in WIGOS are provided in section 2.6. These apply to all WIGOS component observing systems including WHOS.
2. The WMO Hydrology and Water Resources Programme has developed material on the implementation of the WMO Quality Management Framework in Hydrology and its adoption in national operations. Some Members have achieved compliance with the ISO 9001:2015 standard (*ISO 9001:2015 Quality management systems — Requirements*) and examples have been documented to assist other Members.

7.7 CAPACITY DEVELOPMENT

Notes:

1. Provisions for the implementation of capacity development in WIGOS are provided in section 2.7.
2. Whatever the level of technical sophistication of a data-collection authority, the quality of its staff remains its most valuable resource.

7.7.1 Members should undertake careful recruitment, training and management to attain and maintain suitable personnel with the most appropriate skill sets.

7.7.2 Members should pursue a carefully structured training programme for all personnel engaged in field and office practices pertaining to data collection because they are in a strong position to influence the quality of the final data.

Note: Formal training ideally will aim at providing both a general course in basic principles and training modules to teach in-house field and office procedures. All material has to be relevant and current.

7.7.3 Members should provide training classes, follow-up exercises and on-the-job training to field personnel, before they make streamflow and topographic measurements using various technologies such as Acoustic Doppler Current Profiler (ADCP) and mechanical current meters.

7.7.4 Members should provide training classes, follow-up exercises and on-the-job training on data-collection practices and processing of data to increase employee productivity and programme effectiveness.

7.7.5 Members should have appropriate technologies in place, such as hydrological information systems, to allow for streamflow data processing and to facilitate the effective and efficient delivery of metadata, data and data products to users.

7.7.6 Members should have an adequate number of stations to meet priority needs and should ensure sufficient resources to maintain and operate sites to attain required accuracies and reliability of data for their intended use.

8. ATTRIBUTES SPECIFIC TO THE OBSERVING COMPONENT OF THE GLOBAL CRYOSPHERE WATCH

Note: The provisions of sections 1, 2, 3 and 4 are common to all WIGOS component observing systems, including GCW. The provisions in this section are specific to GCW.

8.1 **Cryosphere components shall be: solid precipitation, snow, glaciers and ice caps, ice sheets, ice shelves, icebergs, sea ice, lake ice, river ice, permafrost and seasonally frozen ground.**

Notes:
1. Members may perform observations of any variables of any of these components.
2. Members may use different platforms (fixed stations, mobile platforms, virtual sites and remote sensing) to perform cryospheric observations.

8.2 Members should collaborate actively in, and give all possible support to, the development and implementation of the observing component of GCW.

Notes:
1. The scope of GCW encompasses surface- and space-based observations, the application of observing standard and recommended practices and procedures for the measurement of cryospheric variables, and full assessment of in situ and satellite products.
2. The initial focus of the observing component of GCW is to promote cryospheric observations at existing stations, rather than installing new ones.

8.3 Members should encourage partnerships between organizations to coordinate observing, capacity-building and training activities relevant to cryospheric observations, and to assist with the compilation and development of standard and recommended practices and procedures for cryospheric observations.

8.4 **Members concerned shall ensure that their observations from GCW stations are accessible through the GCW data portal.**

Notes:
1. This is the specific means for GCW stations to comply with provision 2.4.4.1.
2. By ensuring their GCW station observations are made available, Members are helping to promote the incorporation of cryospheric observations into GCW data products and services.

8.5 **Members concerned shall clearly identify in OSCAR/Surface which stations belong to the GCW surface observing network and which belong to CryoNet.**

8.6 **Members operating stations of the GCW surface observing network shall apply GCW best practices and procedures.**

Note: Global Cryosphere Watch best practices and procedures are published in the *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume II. Such guidance material will help Members to understand and comply with technical regulations.

8.7 **The GCW surface observing network shall comprise a core component, called CryoNet, and stations of affiliated networks.**

Notes:
1. Members are encouraged to apply GCW recommended best practices at all cryosphere-observing stations in existing programmes and networks, and to apply for the designation of these stations as CryoNet or CryoNet contributing stations. The Global Terrestrial Network for Permafrost (GTN-P) is one such network; it is responsible for defining monitoring strategies and establishing data protocol for its network. Stations in the WMO RBON, which measure at least one cryospheric variable, already follow WMO guidelines for observation standards and exchange protocols.

2. Guidance on the process for applying for designation as a GCW station and the criteria for acceptance are available at https://globalcryospherewatch.org/ and in the *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume II.
3. Guidance regarding which networks are identified as affiliated networks, and how their non-designated stations are identified as components of GCW (either as CryoNet or CryoNet contributing stations), is available at https://globalcryospherewatch.org/ and in the *Guide to Instruments and Methods of Observation* (WMO-No. 8), Volume II.

8.8 The basic constituent part of the GCW surface observing network shall be a GCW station.

Note: A GCW station could be a CryoNet station, a CryoNet contributing station, or a station of an affiliated network.

8.9 CryoNet shall comprise CryoNet stations, CryoNet contributing stations, and CryoNet clusters.

8.10 A CryoNet station shall meet the minimum set of requirements specified in Appendix 8.1, Part I.

8.11 A CryoNet station shall be either a primary or a reference station:

(a) A primary CryoNet station shall be intended for long-term operations and make at least a four-year initial commitment;

(b) A reference CryoNet station shall have a long-term operational commitment and data records of at least 10 years.

Note: Any CryoNet station may have one or more additional attributes:

(a) It can be a calibration/validation station, used for calibration and/or validation of satellite products and/or Earth system models, or it has been used for such purposes in the past and still provides the necessary facilities;

(b) It can be a research station having a broader research focus related to the cryosphere.

8.12 A CryoNet contributing station shall be a station that provides or provided observations of one or more variables of one or more cryospheric components.

Notes:

1. CryoNet contributing stations that do not satisfy all six requirements listed in Appendix 8.1, Part I, and thus do not meet minimum requirements for a CryoNet station, are nevertheless encouraged to satisfy as many of those requirements as possible.
2. CryoNet contributing stations are not required to provide ancillary meteorological observations. They may be operating in remote, hard-to-access regions, where cryospheric observations are scarce, and they may complement other cryospheric measurement programmes. These stations may have data records that are short or with large gaps.
3. CryoNet contributing stations may have the reference attribute (see 8.11 (b) above).
4. CryoNet contributing stations which have access to meteorological observations from the meteorological station at a representative location, could apply to form together a CryoNet Cluster, in which case the grouping needs to meet the criteria for a CryoNet station.

8.13 A CryoNet cluster shall comprise two or more active stations with coordinated operations or access to data, of which at least one shall be a CryoNet station or a CryoNet contributing station together with a station providing representative meteorological observations, and which together, meet the requirements for a CryoNet station.

8.14 A CryoNet cluster shall meet the requirements specified in Appendix 8.1, Part II.

Note: A CryoNet cluster may cover several microclimatological regions or may extend over larger altitude gradients. Thus, additional ancillary meteorological stations may be part of a CryoNet cluster. Stations in a cluster may be operated by different partners, while their operation is coordinated through one agency or institute.

8.15 **A CryoNet cluster shall be basic or integrated:**

(a) Basic CryoNet clusters shall monitor one component of the cryosphere and shall observe multiple variables of that component;

(b) Integrated CryoNet clusters shall monitor at least two components of the cryosphere or at least one cryosphere component and one other part of the Earth system. Integrated clusters shall promote, through worldwide scientific collaboration, progress in the scientific understanding of the processes that change the cryosphere.

Note: Typically, integrated clusters have a broader research focus than basic clusters. Whereas basic clusters investigate only the cryosphere, integrated clusters aim to provide a better understanding of the cryosphere and its linkages to other parts of the Earth system, for example, the atmosphere, the hydrosphere, the biosphere, the oceans, soil or vegetation.

APPENDIX 8.1. MINIMUM REQUIREMENTS FOR GLOBAL CRYOSPHERE WATCH CRYONET STATIONS AND CRYONET CLUSTERS

I. MINIMUM REQUIREMENTS FOR A CRYONET STATION

1. Core CryoNet measurement requirements: **The station shall measure at least one variable of one of the cryospheric components. The station location shall be chosen so that cryospheric measurements are representative of the surrounding region, and such representativeness shall be described.**

2. Commitment of operational continuity: **The station shall be active. The responsible agencies shall be committed, to the extent reasonable, to sustaining long-term observations of at least one cryospheric component. There shall be a commitment to continuing measurements for at least four years.**

3. Up-to-date and available metadata: **The station metadata, including all metadata describing the station characteristics and observing programme, shall be kept up to date and provided to the Global Cryosphere Watch (GCW) portal and to the WIGOS Information Resource (WIR)** – OSCAR/Surface**.**

4. Compliance with regulatory practices: **The station observational procedures, instruments and methods of observation, quality control practices, and so forth, shall follow GCW-endorsed regulations.**

5. Freely available data and ancillary data: **Data shall be made freely available and, whenever possible, in (near) real time. In situ ancillary meteorological observations, as required by CryoNet practices, shall also be available with documented quality.**

6. Competency of staff: **Personnel shall be trained in the operation and maintenance of the station.**

II. REQUIREMENTS FOR A CRYONET CLUSTER

1. A cluster should encompass observations over an area larger than a conventional observing station;

2. **Integrated clusters shall have technical support staff;**

3. **Integrated clusters shall have training capability;**

4. **There shall be a long-term financial commitment for the comprising stations;**

5. **Data shall be made freely available and, whenever possible, in (near) real time.**

6. **A cluster concept outlining the research approach, data access and use, and relevant engagements shall be provided in support of registration.**

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